New Scientist

WEEKLY 11 February 2023

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Virtual event

Fermilab: Solving the mysteries of matter and energy, space and time

Join Fermilab senior scientist Don Lincoln as he explains what the particle physics facility in Illinois has taught us about our universe. Major discoveries made at Fermilab include the top and bottom quarks – and future work there might be critical for a "theory of everything". Online on 4 April at 6pm GMT/1pm EST. Early booking tickets are £14.

newscientist.com/events

Tour

Vietnam: Caves, conservation, culture

Explore Hang Tien cave and cruise Ha Long Bay in this 13-day tour of Vietnam. Along the way, you will view stunning landscapes, learn about the country's geology and visit conservation facilities founded to protect animals including gibbons and langurs. Tour begins on 22 May and costs £3229.

newscientist.com/tours

Podcast

Weekly

Podcast editor Rowan Hooper and the team discuss the discovery that chimpanzees have sclera – the white part of the eye around the iris – and there is news of bacteria-killing proteins designed by artificial intelligence. Plus, in a bonus episode, TV columnist Bethan Ackerley chats about *The Last of Us* and killer fungi with fungal pathogen researcher Matthew Fisher.

newscientist.com/nspod

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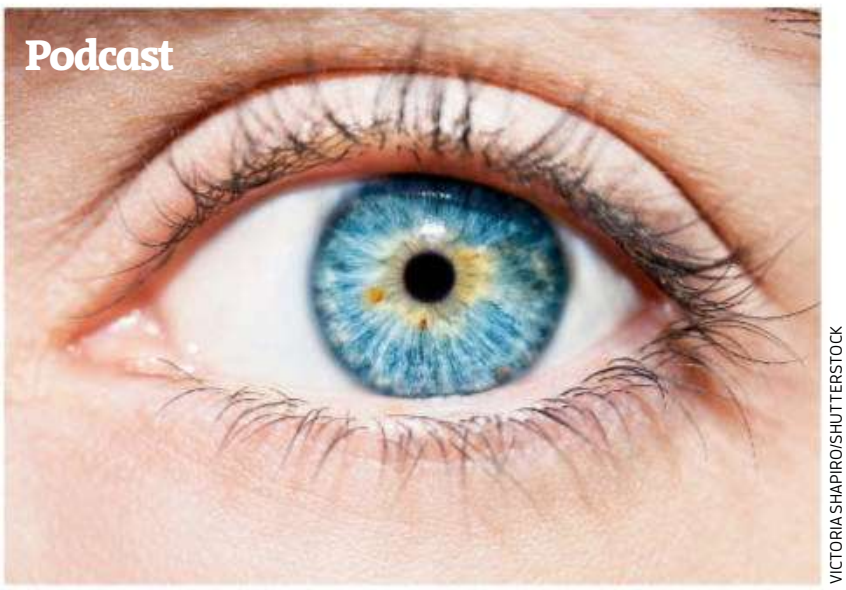
Sea view Cruise Vietnam's spectacular Ha Long Bay



VICTORIA SHAPIRO/SHUTTERSTOCK

Eye whites We have only just realised that chimps have them too

Video

Mongoose manoeuvres

On our YouTube channel this week, there is footage of researchers in Uganda studying the fighting tactics adopted by banded mongooses (*Mungos mungo*). These carnivorous mammals are known to engage in long-running, bloody battles and studying their behaviour might offer insights into the evolutionary basis of human warfare.

youtube.com/newscientist

Newsletter

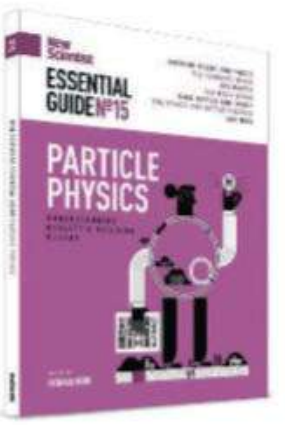
Fix the Planet

Researchers have developed a carbon-recycling system that could cut the carbon emissions from steel industry blast furnaces by 90 per cent, says environment reporter Madeleine Cuff. The technology is attracting interest from steel companies, but there is work to do to make it commercially viable.

newscientist.com/fix-the-planet

Newsletter

"We are turning carbon dioxide into a useful part of the blast furnace reaction"



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Power down

The 2000-watt challenge is a valuable guide to using less energy without suffering

WITH fuel bills and gas prices vastly higher as a result of Russia's invasion of Ukraine, for many of us, the question of cutting back on energy use isn't one of if, but how. So where to start?

Perhaps a thought experiment from Swiss researchers could help. If you shared all the energy produced in the world, everyone would get roughly 2000 watts of continuous power, the equivalent of 48 kilowatt-hours a day. Those who made this calculation in the 1990s envisioned a 2000-watt society, where everyone had access to no more, no less.

This idea is appealing for several reasons. It takes what can feel like trivial or arbitrary lifestyle changes and puts them towards a specific goal. How much closer will you get to 2000 watts by foregoing the tumble dryer or by cycling to work? It is also based on principles of equity, forcing us to think less about how much we would like and more about how much there is to go around. Adding to the appeal, the Swiss vision of a 2000-watt society is one where everyone can still live comfortably.

"The Swiss vision of a 2000-watt society is one where everyone can still live comfortably"

You don't have to forego the good life.

If that all sounds idealistic, it is because it can be. As our New York City-based reporter found in our cover story this week (see page 36), getting to 2000 watts is no picnic there (the average person in the US uses energy at four times this rate).

Still, it is a worthwhile challenge, if you dare to accept it, not least because it brings into focus the limitations of our personal decisions when it comes to energy consumption. Your energy budget will quickly get used up by things that are out of your control, such as public transport or street lighting.

Which brings us to what is perhaps the most important thing about this thought experiment. It only works if everyone is involved – including governments, which can have an outsized impact by enacting low-energy policies. It is rarely politically popular to focus on less rather than more, but our Swiss friends have shown us that, paradoxically, the more investment there is in helping people live on less, the better off we all are. ▮

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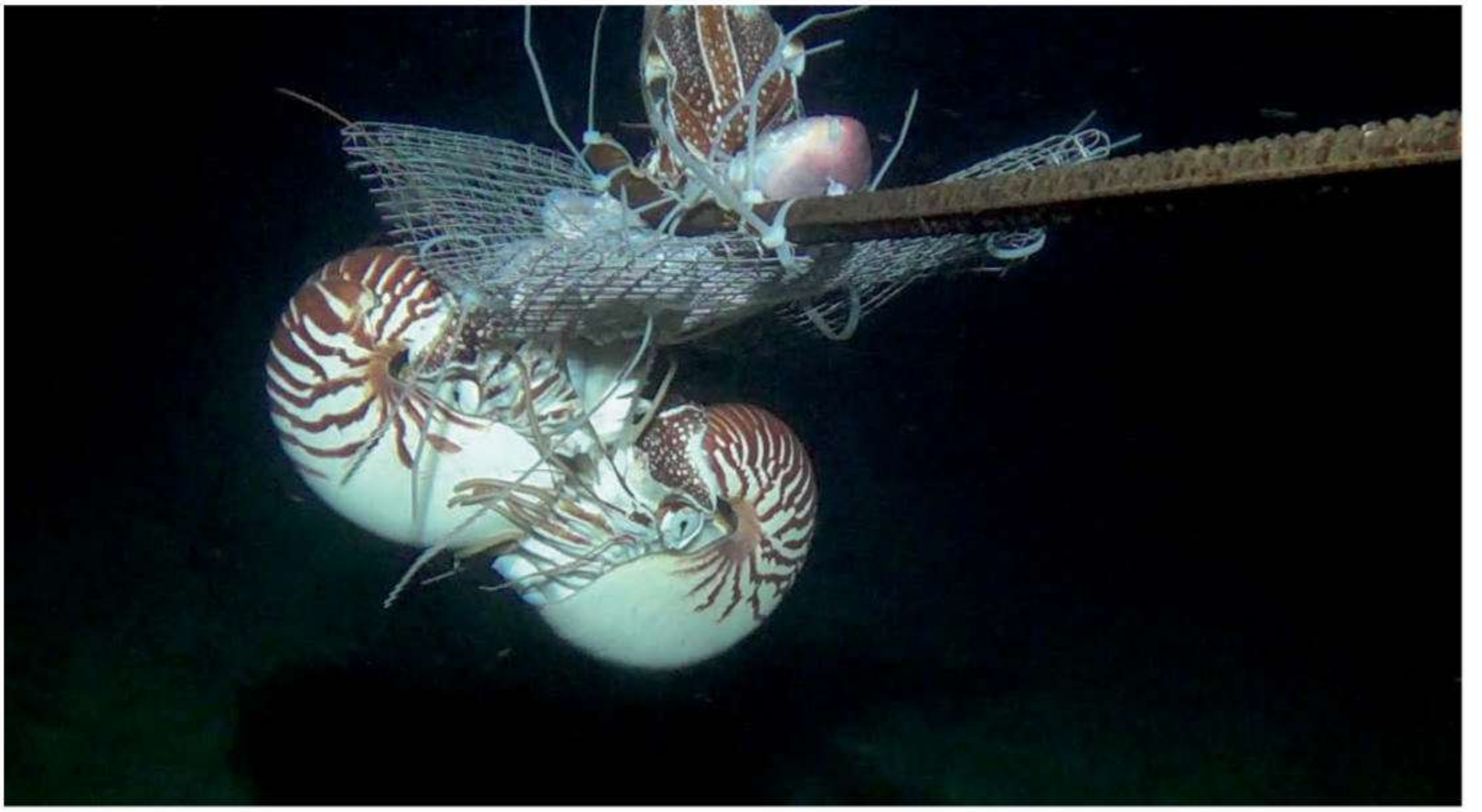


GREGORY BARORD

Zoology

Spiral-shelled trio

Three nautilus species new to science have been found near islands in the South Pacific, reports **Jake Buehler**

THREE kinds of nautilus have been identified as separate species, thanks to their differing physical features.

Hundreds of millions of years ago, these spiral-shelled relatives of octopuses and squids were far more diverse, with thousands of species known from fossils. But today, only about six species live on the deep slopes of coral reefs around Indonesia and parts of the western Pacific Ocean. The precise number of living nautilus species has remained unsettled among researchers.

Many populations that haven't been well-studied – such as those found near islands in the South Pacific Ocean – have traditionally been considered part of the wide-ranging *Nautilus pompilius*, says Greg Barord at Central Campus, Des Moines Public Schools in Iowa.

But a 2017 genetic study suggested that nautiluses found in Fiji, Vanuatu and Samoa were distinct from other nautiluses and perhaps each other. Barord and his colleagues examined shells from museum specimens and recently collected animals found near the islands, comparing their shape, colour and patterning with nautiluses from elsewhere. They found that each population's physical features were distinct, and formally named and described them as three separate species (*ZooKeys*, doi.org/grqg6g).

Nautilus samoaensis from Samoa has a branching pattern to its dark orange shell stripes not found in other species. *Nautilus vitiensis* from Fiji is relatively small and has very little striping on its white shell. In contrast, much of the shell of *Nautilus vanuatuensis* (pictured) from Vanuatu is covered in thick, dark stripes.

"The precise number of living nautilus species has remained unsettled among researchers"

***Nautilus vanuatuensis* lives near Vanuatu in the South Pacific**

The gas-filled chambers of a nautilus shell implode below 800 metres deep, and nautiluses don't tolerate the warm surface waters in the tropics. These factors might keep the animals stuck around the underwater slopes near these islands, causing populations to differentiate from each other over time. Barord thinks there are probably other undescribed, endemic nautilus species on similar island chains. ▮

Briefing Bird flu

Can bird flu spread among mammals?

Bird flu infections have been recorded in animals such as foxes and mink, but it is unclear if the virus can go from one mammal to another, reports **Madeleine Cuff**

THE world is in the midst of its largest-ever outbreak of bird flu and there is evidence that mammals are being infected too. Here's what you need to know.

OWEN HUMPHREYS/PA IMAGES/ALAMY

National Trust rangers collecting dead birds in the Farne Islands, UK, in 2022

What is the current situation?
Since October 2021, when the latest outbreak began, the H5N1 subtype of the virus has spread through seabird colonies, farmed poultry and wild flocks across the US, Europe and beyond. Globally, around 15 million domestic birds have died from bird flu over the past 15 months, and more than 193 million have been culled to stop the virus spreading to other flocks.

There is little authorities can do to limit the spread, apart from try to keep farmed birds away from wild populations. Since November 2022, all farmed birds in the UK, including those being reared as free range, have been subject to a mandatory housing order, meaning they must be kept inside until further notice. From this month, "free range" labels will start disappearing from egg cartons across the country.

> **"If the virus adapts to mammalian species, that increases the risks to humans"**

Is the outbreak spilling over into mammals?
The virus has been detected in a range of mammal species, from foxes in England to mink in Spain, grizzly bears in the US and seals in the Caspian Sea.

The World Organisation for Animal Health (WOAH) told the BBC there have been 119 recorded outbreaks of bird flu affecting mammals since October 2021, with about 200 individual cases recorded.

In the UK, statistics from the Animal and Plant Health Agency (APHA) suggest there have been outbreaks in otters and foxes. Some 49 mammal carcasses infected with bird flu were collected in 2021, 119 in 2022 and four so far this year.

Have we got a complete picture of what is happening?
WOAH warns that the number of mammalian infections is likely to be underreported, due to the difficulty of surveilling wild animals across continents. The UK Health Security Agency has also warned that there is "very limited surveillance" of mammals to monitor the spillover risk across the country.

It is unclear whether mammals always catch the virus directly from birds, or if it is spreading between mammals. Studies by Wageningen Bioveterinary Research in the Netherlands show there is no spread of the H5N1 virus between wild mammals such as foxes, with evidence suggesting those animals became infected independently of each other by eating infected wild birds.

"What we don't have any evidence of is that it can then go from fox to fox, or otter to otter – so these are what we call dead-end infections," Ian Brown at APHA told BBC Radio 4 on 2 February.

However, genetic sequencing of the virus from an October 2022 outbreak on a mink farm in Spain suggests the animals were infected with a new variant of H5N1 with a mutation that might help it spread between mammals.

Research is also ongoing to establish whether an outbreak that left more than 700 seals dead in the Caspian Sea in December 2022 could provide evidence of mammal-to-mammal transmission, according to the *i* newspaper.

More investigation is needed before mammal-to-mammal transmission is confirmed, says Munir Iqbal at the Pirbright Institute, UK. The virus in the mink farm could have spread via a contaminated water source or feed, he says. "If one animal is infected and they are all sharing the same water, then probably it is through water," he says.

Can humans catch bird flu?
Humans can catch the virus, but it is rare. Over the past 20 years, across multiple outbreaks, there have been almost 870 cases of human infection with H5N1, of which 457 were fatal, according to the World Health Organization.

Symptoms include a high temperature, aching muscles, headache and a cough or shortness of breath. People who come into close contact with infected birds are most at risk, and the public is advised to avoid getting close to wild birds and poultry. Currently, there is no evidence that the bird flu virus can pass between humans.

Yet researchers are worried that if the H5N1 virus mutates to transmit between mammals, it could soon be able to jump between humans. "If the virus was able to transmit between wild animals, then it would mean that the virus could sustain in those animals," says Iqbal. "If the virus adapts to mammalian species, that increases the risks to humans." ▮

15 million
Domestic birds killed by bird flu in the past 15 months worldwide

119
Outbreaks of bird flu affecting mammals since October 2021

870
Human cases of H5N1 bird flu recorded by the WHO since 2003

Environment

US megadrought has led to more air pollution from power plants

James Dinneen

WATER levels at reservoirs across the western US have hit record lows, reducing the amount of energy generated at dams. Fossil fuel power plants are filling the hydropower gap, leading to more greenhouse gas emissions and air pollution during the region's megadrought.

On average, about 26 per cent of the electricity for the western US comes from hydropower and 50 per cent comes from fossil fuel plants burning gas, coal or oil. The rest is from wind, solar and nuclear power and other sources, such as geothermal energy.

Under drought conditions, the proportions in that mix can change, says Minghao Qiu at Stanford University in California. Less water in reservoirs means less water to release, leading to reductions in hydropower. The Hoover Dam on the Colorado river, for instance, is currently generating less than half its usual output because it draws water from a shrinking Lake Mead.

Qiu and his colleagues analysed the effects of drought on electricity generation in 11 states in the western US, using data collected between 2001 and 2021 on precipitation runoff into reservoirs, electricity generation and resulting emissions.

They found that during the most extreme drought conditions, the electricity generated by fossil fuel plants increased as much as 65 per cent above average at some facilities. During the driest months, plants in California saw average increases of 35 per cent, while the Pacific Northwest and the Southwest saw increases of 11 and 9.5 per cent, respectively.

These "drought-induced shocks" accounted for 12 per cent of total carbon dioxide emissions from electricity generation over that period, say Qiu. They also accounted for 8 per cent of sulphur dioxide emissions and 6 per cent of nitrogen oxide emissions.

Both sulphur dioxide and nitrogen oxide emissions contribute to a harmful type of pollution called PM2.5, which refers to particles between 1 and 2.5 micrometres in diameter. These particles can penetrate deep into lung tissues and are responsible for most deaths from air pollution (EarthArXiv, doi.org/jvv3).

"It's not just drought," says Nathalie Voisin at the Pacific Northwest National Laboratory in Washington state. "It also has impacts on air quality."

While previous research used statistical models to show that drought might boost pollution, the new study used data from air quality monitors downwind of fossil fuel power plants to confirm this is the case, finding increased pollution from PM2.5, especially within 50 kilometres of the plants. "It's surprising to actually see this in the real world," says Qiu.

Drought-induced air pollution has decreased in the US in recent years because many coal-powered plants have been supplanted by natural gas, which produces fewer emissions. Also, more power plants are using scrubbers to reduce pollution. But in countries that use a large amount of both hydropower and coal and oil, such as Madagascar or Honduras, drought-induced shocks would cause more air pollution, says Qiu.

35%

Increase in electricity from fossil fuels during dry spells in California

"Even with a very expansive renewable energy transition this drought-induced fossil problem doesn't really go away," he says. Overall emissions go down as renewable sources are added, but even ambitious clean energy scenarios show fossil fuels being used to fill in drought-induced gaps for decades. ▮

Technology

Suspected Chinese spy balloon shot down by US jet

A US fighter aircraft destroyed a suspected Chinese surveillance balloon on 4 February after it flew over the US, including above sensitive military bases.

The balloon entered Alaskan airspace on 28 January and crossed Canada before returning to US airspace over Idaho on 31 January. The incident has raised international tensions, leading US secretary of state Antony Blinken to postpone a planned visit to China.

According to the US, the balloon was on an intelligence-gathering mission, travelling over military sites such as missile silos. China claims the balloon was for meteorological observation and blew off course.

US officials say similar balloons flew over the US at least three times during Donald Trump's presidency and once earlier in Joe Biden's, but this flight was the longest in duration and it is the first time details have been made public.

They also say balloons of this type have been spotted over countries in Asia and Europe, while another has recently been sighted over Costa Rica and Venezuela.

Biden gave orders to shoot down the balloon on 1 February, but it was several days before it could be done without risk to civilians.

The balloon was eventually destroyed by an F-22 Raptor jet just off the coast of South Carolina. The aircraft fired an AIM-9X missile from an altitude of nearly 18,000 metres (58,000 feet) at the balloon, which had been moving at a height of 18,000 to 19,800 metres.

REUTERS/RANDALL HILL

This Chinese balloon was destroyed by a missile off the US coast on 4 February

"Shooting the balloon down addressed the surveillance threat posed to military installations and further neutralised any intelligence value it could have produced, preventing it from returning to the PRC [People's Republic of China]," said an unnamed senior US defence official on 4 February.

The US Navy and FBI are working to recover the wreckage, which came down in water only 15 metres deep, but spread out across an area spanning 11 kilometres. ▮

Matthew Sparkes

Artificial intelligence

The trouble with image generators

Artificial intelligences' ability to produce close copies of the images used to train them could be significant when it comes to settling copyright infringement lawsuits, finds **Alex Wilkins**

DO IMAGE-GENERATING artificial intelligence (AI) models infringe artists' copyright? With legal action already under way against some of the companies behind these AIs, researchers have now found that some generators can occasionally reproduce some of the specific images used to train them – a discovery that could play into the upcoming lawsuits.

Popular text-to-image generators like Stability AI's Stable Diffusion and OpenAI's DALL-E 2 use diffusion models, which work backwards from random noise to produce images similar to those that they have seen before. To work well, these models must be trained on a vast number of images, paired with text captions, which are often taken from the internet without necessarily seeking the owners' permission.

This practice has drawn criticism from some who argue that the models are violating copyright. In the UK, Getty Images is suing Stability AI because it claims the firm "infringed intellectual property rights" by using Getty's images for training. A second lawsuit against Stability AI has been filed in the US by a group of artists for allegedly violating US copyright law.

One possible legal argument for the AI companies to use is that their models aren't directly using the copyrighted work, but merely being "inspired" in the same way that a human artist would be.

But now, Florian Tramèr at the Swiss Federal Institute of Technology in Zurich and his colleagues, including researchers at Google, have demonstrated that Stability Diffusion and Google's Imagen model can almost exactly reproduce images from their training data, suggesting that they are, in some sense, stored within the parameters of the models.

CORNELL UNIVERSITY/EXTRACTING TRAINING DATA FROM DIFFUSION MODELS

Left: an image from Stable Diffusion's training data with the caption "Ann Graham Lotz". Right: the image produced by Stable Diffusion when prompted with "Ann Graham Lotz"

"The claimants will probably bring up this research and the defendants will have to deal with it"

350,000
Text prompts used to test the Stable Diffusion AI

109
Images produced by the Stable Diffusion AI that were copies of training data

To demonstrate this, Tramèr and his team looked at the training data used in these AI models, identifying images that appeared multiple times and so were more likely to be memorised. They then entered the captions for these images as text prompts for the AIs, using 350,000 prompts for Stable Diffusion and 1000 for Imagen, generating 500 images for each prompt.

When they compared these outputs to the original training data, they found that Stable Diffusion produced 109 images and Imagen 23 that were mathematically similar enough to images in their training sets to be considered reproductions. Visually, these images were often near identical, with only small artefacts like noise or compression (arxiv.org/abs/2301.13188).

Matt Hervey, head of artificial intelligence law at legal firm Gowling WLG in London, says the team's work is likely to play a role in lawsuits against AI companies. "I would expect that the claimants will bring up this research and the defendants will have to deal with it, perhaps trying to show that the research is wrong, or that the extent of memorisation is negligible or that this sort of memorisation is not copyright infringement," he says.

OpenAI has acknowledged that, during development, predecessors to DALL-E 2 reproduced images used to train the model, but the company claims to have mitigated this before making the AI public. Stability AI has also removed duplicate images in the newest version of Stability Diffusion. OpenAI and Stability AI didn't respond to requests for comment on this new work.

While removing duplicates is a good first line of defence, says Tramèr, it won't eliminate the possibility that these models could still reproduce training data. It is also difficult to achieve, because automated methods for removing duplicates may struggle to identify very similar images with only subtle differences.

"If the model at any time just generated an image from the training set, but slightly rotated it, our current evaluation set-up wouldn't be able to find this because we only look for sort of exact pixel level matches," says Tramèr.

Part of the problem is that we still don't really understand why AI models memorise certain things over others. For example, a model trained on many images of a single cat might then reproduce that specific cat when asked for a cat in general, says Tramèr, but it is difficult to identify when this would happen.

"This black box nature is really prevalent in all deep learning models," says Yi-Zhe Song at the University of Surrey, UK. "Nobody understands anything."

To address this, AI creators must find ways to more closely manage their training data to avoid copyright violations, he says. "But I don't think this is something that's easily solvable." ▮

Technology

Diving drone can switch between flying and swimming

Matthew Sparkes

A QUADCOPTER that can fly like an aerial drone, but also splash down into water and operate like a submersible, could be used for search and rescue missions or engineering inspections.

Ben Chen at the Chinese University of Hong Kong and his colleagues created a prototype device called Mirs-X, which weighs 1.63 kilograms and is 38 centimetres wide. It can hover for 6 minutes in the air or dive underwater for around 40 minutes. Mirs-X is waterproof at depths of up to 3 metres and moves at up to 2 metres per second in water (arxiv.org/abs/2301.12344).

Its propellers spin rapidly to create lift in the air, but because water is far more dense, they have to turn much more slowly underwater. This is achieved by a dual-speed gearbox for each motor.

In air, the drone manoeuvres by altering the speed of its propellers to tilt the craft. But in water, this is much less effective, so the machine is fitted with rotating mounts that can tip the motor and propeller in different directions to create sideways thrust.

Chen says that future, larger versions of the device could be helpful for search and rescue operations, observing from high altitude and then descending into water for a closer look, or for carrying out engineering inspections of bridges and tunnels.

The researchers intend to scale up the prototype into a drone that is around 2 metres across, equipped with sonar and cameras. The existing prototype has been tested in a swimming pool, but a larger one would have to be tested in the sea or a river, says Chen.

"If we want it to have some real applications for industry, we really need to scale the platform. You need a longer endurance; you need a bit more payload," he says. ▮

Biology

Coronavirus mutations offer a new insight into evolution

Michael Le Page

THE genome sequences of millions of individual SARS-CoV-2 viruses have enabled researchers to study evolution in a way that wasn't possible before. The coronavirus's global proliferation means that we have a sufficient amount of sequence data to track every possible mutation that affects a single letter of its RNA and the impact these have on the pathogen's fitness.

The findings could help us develop drugs that target parts of the virus's proteins that can't easily mutate to evade existing drugs, says Jesse Bloom at the Fred Hutchinson Cancer Center in Seattle, Washington.

By monitoring the growth of coronavirus variants, it is possible to identify some of the single-letter mutations that confer an advantage for the virus. The letters relate to four bases that make up part of the virus's genetic backbone. But these single-letter mutations are just a tiny fraction of all possible mutations.

The coronavirus continues to mutate as it spreads globally

What Bloom and Richard Neher at the University of Basel, Switzerland, realised is that because SARS-CoV-2 has proliferated so greatly in the ongoing global pandemic,

15,000

The average number of times that every possible single-letter RNA mutation has occurred in the SARS-CoV-2 coronavirus

every possible single-letter RNA mutation has happened 15,000 times on average. What's more, the millions of sequenced samples give us a way to assess the results of these natural experiments.

Using millions of publicly available SARS-CoV-2 sequences, the pair first counted how often mutations had occurred in sites where all single-letter mutations are known to be neutral, because they don't result in any change in protein sequence. This told them how many mutations would occur in any site without affecting viral fitness.

They then compared the number of observed mutations per site to this expected number. If the number of observed mutations is lower, then viruses with a specific mutation are more likely to die out and all such mutations are harmful. If it is higher, all these mutations must be beneficial.

Bloom and Neher then mapped the results onto all the SARS-CoV-2 proteins to reveal which sites must be in a particular state for the virus to be successful and which sites can tolerate changes (bioRxiv, doi.org/jvxd).

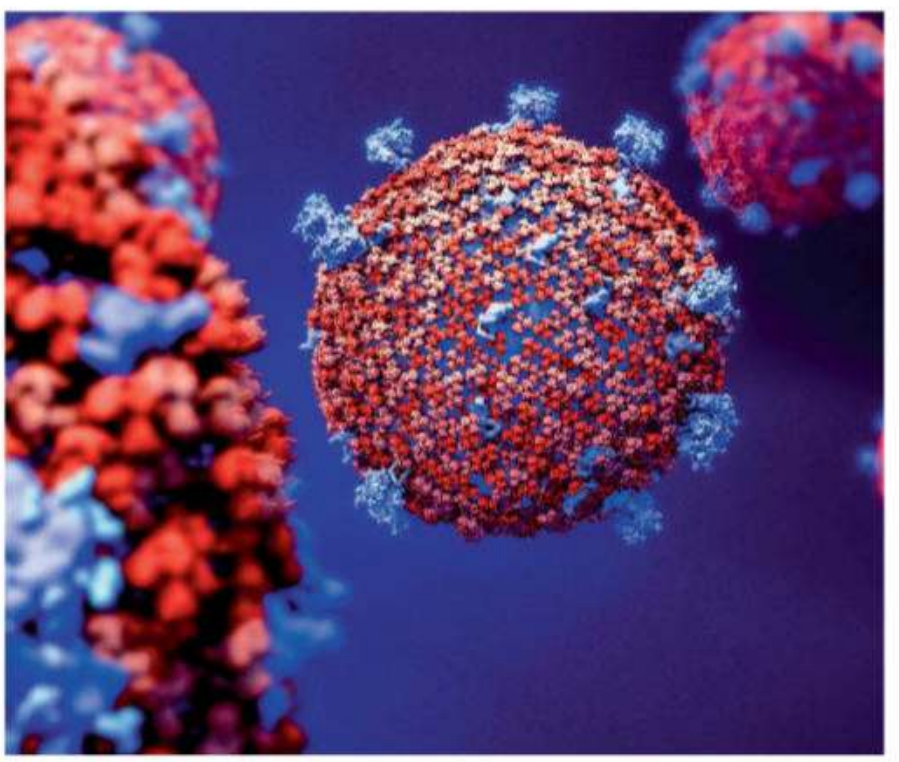
This could be applied to any organism that exists in sufficient numbers for every single-letter mutation to have occurred multiple times, and for which we have enough sequence data.

"A species such as tigers or elephants doesn't have enough living individuals," says Bloom.

But in 2015, Jay Shendure at the University of Washington in Seattle pointed out that there are enough people that we could observe every mutation that doesn't affect our survival if we sequenced a large proportion of the human population, which now stands at 8 billion.

"This strategy could be applied to any organism with enough sequence data, like humans"

"I think it's less a question of 'if' than 'when'," says Shendure. We haven't sequenced nearly enough human genomes yet, he says. "But if current trends continue, then it will happen eventually." ▮



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Technology

Smart dairy farms are using AI scanners to monitor cows' health

Christa Lesté-Lasserre

A SCANNING system combined with artificial intelligence is automatically assessing cows' health status twice a day on dozens of "smart" dairy farms across the UK.

Overhead three-dimensional cameras film the animals' backs as they leave the milking barn, while sensors read their individual identity tags. The associated computers then use machine learning to process the data, providing farmers with critical daily information about each cow's weight, body condition and mobility, says Wenhao Zhang at the University of the West of England (UWE) in Bristol, UK.

"We can detect certain health conditions, including lameness, just by scanning the cows walking past, without even having to see their hooves," says Zhang, who presented the research at the 2022 Conference of the International Society for Equitation Science in Hartpury, UK.

Poor body condition and lameness in cattle reflect pain, and affected cows generally produce less milk. Delays in veterinary care can lead to poor welfare, more complex treatments, higher costs and the deaths of animals.

While farmers are well trained to recognise such issues as early as possible, they often miss subtle, day-to-day changes in individual cows. Because they are a prey species, cows will also instinctively hide signs of discomfort, such as limping, when they think they are being watched, says Melvyn Smith, who designed the system with Mark Hansen, both at UWE.

Health problems in dairy cows can be hard for farmers to spot

ALAN HOPPS/MOMENT RF/GETTY IMAGES

In an initial study of 200 dairy cows on one farm, Smith, Hansen and their colleagues placed a computer and 3D cameras in a milking barn. They aimed the cameras over a narrow walkway that cows pass through when they are finished milking. An ear tag reader, set at the cows' head level, triggers the cameras to record.

"The beauty of this equipment is that it's just passively sitting there, unobserved by the animal," says Smith. "And every time they go past – so every time they're milked, which is usually twice a day – it's gathering data."

The system estimated body weight with an accuracy of 95 per cent, says Smith. Body condition scores, based mainly on flesh and fat measurements over the back and hips, were equivalent to the consensus score given by several trained experts, and more reliable than those given by individual experts.

The system also assessed spine movements to find asymmetries caused by lameness, which were confirmed by physical exams by the researchers. A more in-depth analysis even pointed to the specific leg that was in pain, says Smith.

Kate Dutton-Regester at the University of Queensland in Australia says the system is "a great innovation". "The dairy industry needs an automated, non-intrusive monitoring system that can aid dairy farmers in observing the health of their herd in a timely and efficient manner, and this technology meets those criteria," she says. ▮

Neurology

Human neurons integrated into rats' brain

CLUMPS of lab-grown human neurons have been integrated into the brains of adult rats with damaged visual cortices. The human cells even took over some functions of the rats' visual system.

Isaac Chen at the University of Pennsylvania and his colleagues cultured human stem cells, which can develop into many different types of cell, for 80 days so that they formed a three-dimensional tissue culture of brain cortex cells. These make up the outer layer of the brain and play a key role in various functions, such as vision.

Next, the team removed a portion of the visual cortex in 46 rats, before transferring the lab-grown neuron clumps, called organoids, to the cortices. After two months, the organoids showed a neuronal response, measured by putting an electrode into an organoid while a rat watched images on a screen.

One set of images consisted of flashing lights, while another had black and white lines in various orientations, such as diagonally.

The organoids' neuronal response altered alongside the flashing lights and the orientation of the black and white lines (*Cell Stem Cell*, doi.org/grqmqj). This suggests that the neurons were taking over the visual system's function in some of the rats, says Chen.

The researchers also compared the rats that had transplanted organoids with those that had no visual cortex damage. The neuronal responses were relatively similar, but fewer neurons responded to the lights in the rats with the organoids than in their undamaged counterparts, says Chen.

"We hope this study moves us towards transplanting organoids into patients with brain injuries"

"We hope this study moves us in the direction of restoring function using these organoids and eventually leads to, in the long term, transplanting organoids into patients with brain injuries."

The study shows transplanted organoids integrate into host tissue and can restore lost complex functions, says Laura Ferraiuolo at the University of Sheffield, UK. ▮

Jason Arunn Murugesu

Reproductive medicine

Sperm-sorter aims to find best samples to boost IVF success

Matthew Sparkes

A SIMPLE device made from silicon and glass gently separates healthy sperm from defunct cells without harming them, which could increase the chance of success for in vitro fertilisation (IVF) treatment.

Isolating the most active sperm from a sample is important for fertility treatments such as IVF, but current clinical separation methods using centrifuges can harm the delicate cells.

To see if they could divide sperm gently, Ali Heydari at Tarbiat Modares University in Tehran, Iran, and his colleagues have developed a method that takes advantage of the characteristics of sperm. When there is no liquid flow, sperm tend to move in circular patterns, but when there is a current, this flow of liquid reorients them to face upstream because of their shape, so they swim in that direction. Sperm are also known to move towards boundaries and swim along them.

The researchers' device is made of silicon bonded onto glass, creating four channels – each just 90 micrometres across – containing hollow obstacles.

Injecting a sperm sample into the device with a syringe generates a direction of flow and the obstacles create local low-speed currents that make active sperm cells reorient around them and swim towards nearby reservoirs, where they can be siphoned off, while dead cells and debris are washed through (*Scientific Reports*, doi.org/jvvf).

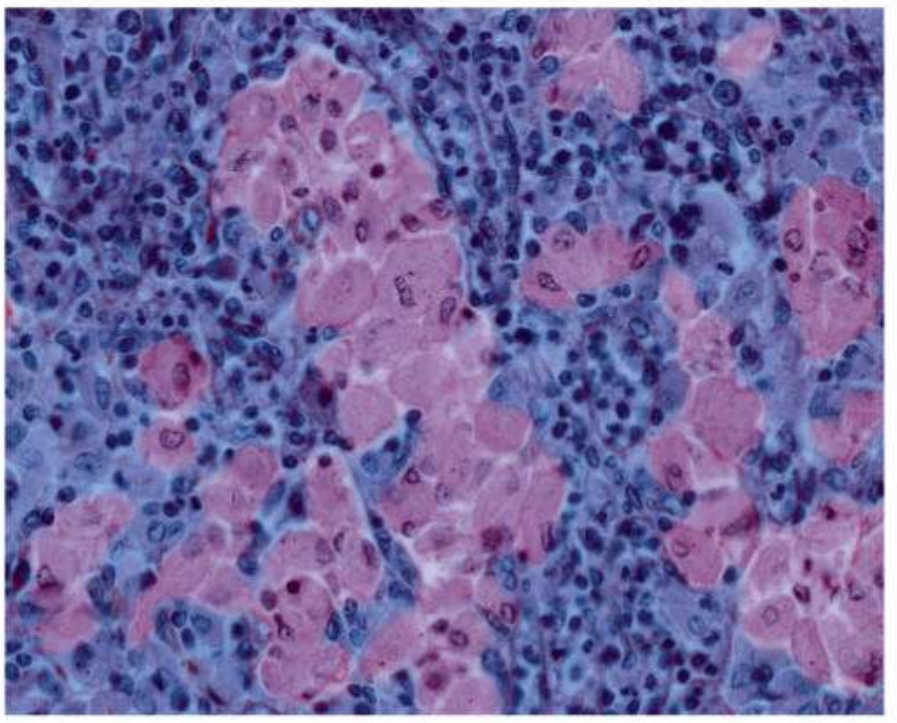
About 40 per cent of human sperm cells injected into the device were mobile, but the researchers found that the proportion of those left in the reservoirs that were mobile was close to 100 per cent.

"Will it improve IVF success rates? I think the jury's out," says Allan Pacey at the University of Sheffield, UK. "But as long as it's equivalent [to centrifuges] and cheaper, it's a good little piece of technology." ▮

Health

Genetic condition may help prevent TB infection

Clare Wilson



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Spleen tissue from a person with Gaucher disease, showing enlarged macrophages in pink

A GENETIC condition called Gaucher disease, which is more common in some Jewish groups, may protect people against tuberculosis, according to a study of the same mutations in zebrafish. This beneficial effect could explain why the condition has persisted.

Ashkenazi Jews, who make up about 8 in 10 of all Jewish people, have a higher than average rate of Gaucher disease, which has symptoms ranging from pain and tiredness to enlarged livers and spleens.

It is caused by the malfunctioning of a type of immune cell called a macrophage, whose job is to engulf and kill bacteria within internal compartments called lysosomes.

Unlike most bacteria, *Mycobacterium tuberculosis* – which is responsible for TB – can survive and reproduce inside lysosomes, allowing the infection to spread within macrophages in the lungs.

There are several hundred mutations that cause Gaucher disease in people with two copies of the mutated gene, but they all result in a kind of fat building up within lysosomes.

Lalita Ramakrishnan at the University of Cambridge and her colleagues investigated the effect of these mutations in zebrafish, which are sometimes used to study TB, as they develop a similar illness when infected with *Mycobacterium marinum*, a close relative of the human TB bacterium.

The team gave the fish the commonest mutations that cause Gaucher disease in Ashkenazi Jews. As expected, fat built up within the lysosomes of their macrophages.

By two measures, the zebrafish were less susceptible to infection. For instance, in a test that involved injecting the fish with one bacterium, 42 per cent of the animals with the mutations stayed uninfected compared with 13 per cent of those without them (*PNAS*, doi.org/jvxc). "The host has a higher chance of killing the bacteria," says Ramakrishnan.

Further experiments showed that the type of fat that builds up inside lysosomes is toxic to the human TB bacterium and the fish equivalent, when grown in a dish. "The accumulation of this fat has a detergent activity. It [disrupts] the membranes of the TB bacteria," says Ramakrishnan.

TB has been a major cause of death among people in Europe over the past centuries, especially those living in crowded conditions. Today, about 1 in 800 Ashkenazi Jewish people has Gaucher disease, but the rate may have been higher a few hundred years ago, when TB was more common in Europe, says Ramakrishnan.

The variants that cause Gaucher disease in Ashkenazi Jews tend to lead to a milder form of the condition than some other mutations, supporting the idea that they could have been selected for because they reduced people's vulnerability to TB, she says.

"The accumulation of fat in cells disrupts the membranes of the TB bacterium"

Mark Thomas at University College London says a different explanation is that the Jewish population was previously small, and so one person's chance mutation was inherited by many of their descendants. "There is good evidence of small population bottlenecks in the Middle Ages, but that does not exclude the possibility of [Gaucher mutations causing] some advantage in some circumstances," he says. ▮

Military technology

The US wants huge drone swarms

Project for coordinating hordes of drones that fly, crawl or swim is raising concerns

David Hambling

A PENTAGON project envisages automated, coordinated attacks by swarms of many types of drones that operate in the air, on the ground and in the water. The idea is raising concerns about whether human oversight of such a "swarm of swarms" would be possible.

The Autonomous Multi-Domain Adaptive Swarms-of-Swarms (AMASS) is a project from US defence research agency DARPA. Most details are classified, but according to US government contract documentation, it will enable multiple swarms of small aerial, ground and underwater drones to work together to knock out enemy defences. The drones will be equipped with a mix of weapons and tools, such as jammers of radar and GPS.

AMASS wouldn't need human assistance on the ground, because the swarms could coordinate across an entire area of operation, such as a country. But there would be people somewhere overseeing and able to step in if necessary.

The project involves creating a control system to enable thousands of units, including drones, submarines and robot tanks to communicate, exchange information and coordinate their actions autonomously. DARPA has given suppliers until 10 February to bid for the $78 million contract.

Gregory Allen at the Center for Strategic and International Studies think tank in Washington DC says the Pentagon has experimented with swarms of hundreds of drones, but larger swarms with land, air and sea components will introduce complexity and make communication more of an issue.

Low-cost drones have proved effective in the Ukraine conflict, where they have destroyed tanks, swamped air defences and damaged the power grid, but these have been individually controlled.

How much human oversight is possible with a mixed swarm is unknown, says Zak Kallenborn at George Mason University in Virginia. "As the swarm grows in size, it'll become virtually impossible for humans to manage the decisions. Autonomy and AI will be needed to make those decisions, with all the brittleness that entails," he says. "A massive drone swarm prone to errors would be a terrifying thing; a new weapon of mass destruction."

It also raises the prospect of the drones being able to use lethal force without direct human oversight, and it isn't clear how AMASS will handle this.

The aim is to keep humans making key decisions, with drones waiting for permission to act if communications fail, a DARPA spokesperson told *New Scientist*.

Kallenborn says that "in theory, AMASS could be entirely non-lethal, carrying out jamming or other non-kinetic attacks in support of other platforms that actually destroy the defences. I think that's unlikely though."

Allen is also dubious that AMASS could carry out its mission without using lethal force. But he says the Pentagon's policy on oversight for autonomous weapons applies only to operational systems, and AMASS hasn't reached that stage yet. ▮

Concept art of flying drones, which may team up with others on land and in the water

ANDY DEAN PHOTOGRAPHY/ALAMY

Space

Wormholes could magnify light by a factor of 100,000

IF WORMHOLES – strange tunnels connecting two regions of space-time – exist, we may be able to spot them by the way they magnify light. This phenomenon, in which light from behind a cosmic object is stretched around the object due to its gravitational field, is called gravitational lensing, and wormholes may be some of the most powerful lenses around.

Gravitational lensing is fairly common in space and is used to probe some of the biggest mysteries of the universe, such as dark matter and the finer points of general relativity, so understanding the lensing signatures of various cosmic objects is crucial. Mian Zhu at the Hong Kong University of Science and Technology in China and his colleagues calculated how a wormhole with an electric charge would magnify and warp the light of objects behind it – an understanding that could also help in the search for wormholes.

They found that while it would be difficult or, in some cases, impossible to distinguish any individual wormhole from a black hole, between groups of each there could be small differences.

Gravitational lensing splits and warps light in such a way that it often produces multiple images of an object. For black holes, the process can result in any number of copies. But for charged wormholes, the researchers found that there can only be either one image or three.

"Wormholes may be some of the most powerful gravitational lenses around"

If there are three, one should be extremely bright and the other two should be slightly dimmer. In these images, gravitational lensing can magnify an object by as much as 100,000 times. If a group of potential wormholes each produced this pattern, that could help confirm that they were wormholes rather than black holes (*Physical Review D*, doi.org/jvm3). The powerful magnification would also be useful for studying the objects being magnified, but it still doesn't guarantee that we could tell what was doing the magnifying. ▮

Leah Crane

Neurology

Amnesia may be worse with milder brain damage

Jason Arunn Murugesu

MEMORY problems related to a type of amnesia paradoxically seem to be worse in people with less severe brain damage compared with those with more damage.

Developmental amnesia most often occurs as a result of a baby receiving too little oxygen while being born. This affects a person's episodic memory, which involves recollecting an experience.

To better understand this, Faraneh Vargha-Khadem at University College London and her colleagues asked 23 people who had been diagnosed with developmental amnesia and 32 people without the condition to complete a series of tests to assess their various cognitive abilities.

The participants with developmental amnesia had worse memory recall than those without the condition. A statistical analysis suggests this wasn't a chance finding.

But among the participants with amnesia, those with more extensive damage to their hippocampus – a brain region that plays a key role in memory – had better recall than those with less extensive damage, as assessed via MRI scans (bioRxiv, doi.org/jvvg).

The brains of people with more extensive damage to their hippocampus may undergo reorganisation so that other parts of the brain take over some of its function, says Vargha-Khadem.

The findings point to the brain's plasticity and its limits, as the participants with developmental amnesia still had worse recall than those without the condition, says Vargha-Khadem.

"I believe these findings are incredibly exciting, as they begin to shed much-needed light on the full potential of brain plasticity while outlining its unavoidable limitations," says Antonina Pereira at the University of Chichester, UK. ▮

Astronomy

Sunquakes may be caused by high-energy electron beams

Leah Crane

WE MAY finally know what causes sunquakes. The source of these strange rumbles within the sun has divided solar physicists for decades, but researchers have now found that they may come from beams of high-energy electrons burrowing through the outer layers of the sun.

Sunquakes are waves in the sun's photosphere – the surface from which its light shines – that ripple across the star like the waves from a pebble tossed in a lake. They are usually associated with strong solar flares, which are powerful eruptions of energy that sometimes fling plasma from the sun into huge tendrils and loops in the solar corona, its tenuous outermost layer.

Despite this apparent connection, it has long been debated whether flares could actually cause sunquakes. "The origin of sunquakes is located deep in the photosphere, while solar flares usually occur in the corona," says Mingde Ding at Nanjing University in China.

It makes sense that it would be extremely hard for an energy release in the corona to cause a disturbance in the photosphere because the photosphere is about 1 trillion times denser than the corona, says Ding. "Just as a tail cannot wag a dog."

12

Solar flares that coincided with sunquakes from 2008 to 2019

Ding and his colleagues examined data from the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) space observatory on 20 flares that occurred during the most recent solar cycle, between 2008 and 2019. The researchers focused their analysis on 12 that occurred at the same time as sunquakes.

They found that 11 of the 12 flares also coincided with blasts of X-rays that hinted at the presence of high-energy electrons, far more of them than accompany solar flares without sunquakes. This supports the idea that the magnetic activity thought to cause solar flares also creates beams of electrons that plunge into the sun's photosphere (*The Astrophysical Journal Letters*, doi.org/jvm9).

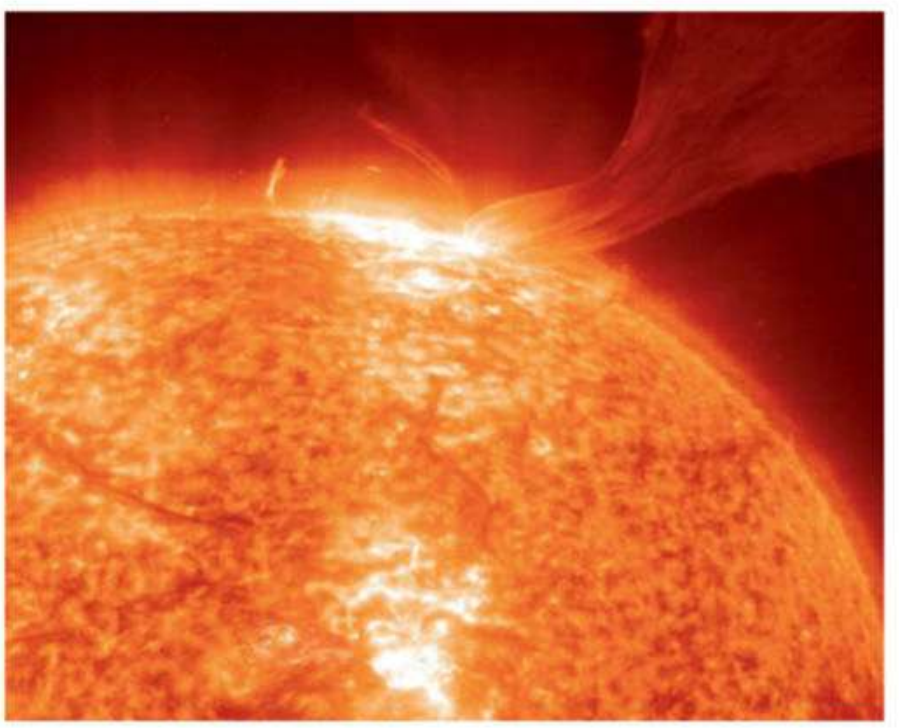
Understanding sunquakes is important because we could use them to probe the areas through which they propagate. "When there are earthquakes we can study the interior of the earth, and when there are sunquakes we can measure the interior of the sun," says Alexander Kosovichev at the New Jersey Institute of Technology.

But it isn't all wrapped up yet: researchers still struggle to explain how the electrons transfer their energy into the sun's plasma to cause a ripple. We also don't know whether any of these mechanisms apply to the quakes observed without strong X-rays.

There are probably multiple mechanisms behind these quakes, the researchers say – the electrons might need some help penetrating the photosphere, and some tremors don't seem to coincide with high-energy electrons at all. "Our work did not provide a full explanation for all kinds of sunquakes, but only a possible scenario in triggering sunquakes," says Hao Wu, also at Nanjing University. "The mystery requires more accurate observation for further validation."

It also requires detailed modelling of how the sun's plasma, magnetic fields and electrons interact with one another. There are several spacecraft observing the sun now, so the data they provide should help researchers finish unravelling the mystery. ▮

Solar flares fling plasma into huge loops in the corona



ESA/NASA/SOHO

Palaeontology

Hunting enormous elephants gave Neanderthals a month-long feast

Clare Wilson

NEANDERTHALS regularly hunted and butchered elephants in Europe thousands of years ago, according to an analysis of marks made on bones by stone tools.

The find suggests these ancient humans either lived in larger groups than previously suspected or that they had ways of processing the flesh so it didn't spoil, says Wil Roebroeks at Leiden University in the Netherlands, given the amount of meat involved. "These elephants are really big calorie bombs."

There has long been debate over whether Neanderthals, distant cousins of modern humans, could have hunted straight-tusked elephants (*Palaeoloxodon antiquus*). These extinct giants stood 4 metres tall, making them larger than woolly mammoths and modern African elephants.

To find out more, Roebroeks's team took a closer look at elephant bones found alongside other animal remains and stone tools in a quarry near Halle, Germany, which was dug out from the 1980s. The bones have been dated to about 125,000 years ago, when Neanderthals were the only humans known to be in the area.

TORSTEN MAUE/WIKIMEDIA COMMONS

A reconstruction of the 4-metre-tall straight-tusked elephant

The remains included those of more than 70 elephants, including a few nearly complete skeletons. The marks on the bones suggest the animals were thoroughly butchered to get every last scrap of meat and fat – including, for instance, their brains and all of the bulky fat pads in their feet (*Science Advances*, doi.org/jvmc).

There were also few gnaw marks left by scavenging carnivores, suggesting little food was left on the carcass. "There's maybe a bit of nibbling on isolated vertebra, but most of these remains were so clean they weren't attractive for carnivores," says team member Lutz Kindler at the Archaeological Research Centre and Museum for Human Behavioural Evolution in Neuwied, Germany.

The team has calculated that all the flesh from one of the elephants would have fed about 100 adults for a month. Some researchers have previously suggested that Neanderthals lived in fairly small groups of up to about 25 people, based on factors such as the size of their caves or analysis of their footprints. "There's a perception they lived in small groups, but when you look for the evidence, there's nothing," says Clive Finlayson at the Gibraltar National Museum, who wasn't involved in the new study.

If a smaller group of, say, 25 people had killed an elephant, they would have had to spend about three to five days working to strip the carcass of flesh and processing it so that it wouldn't spoil, for instance by drying or smoking it, says Roebroeks. The marks on the bones mean the meat wasn't simply left to rot once the Neanderthals had eaten their fill.

The team found a higher proportion of male and older elephants among the remains,

100

Neanderthals would take a month to eat a straight-tusked elephant

suggesting that the Neanderthals were specifically targeting these animals, rather than scavenging from ones that had died of natural causes.

This makes some sense, because in modern elephants, older males tend to live alone. Targeting loners would making hunting easier, says Roebroeks, as they could be driven into traps or muddy shores. "Large mammals are [easier] to kill as long as you are able to limit their mobility, and then they are finished off with spears," he says. ▮

Technology

Google AI creates backing tracks for singers

AN ARTIFICIAL intelligence called SingSong can generate a musical backing track to accompany recordings of people's singing.

To develop SingSong, Jesse Engel and his colleagues at Google Research used an algorithm to separate the instrumental and vocal parts in 46,000 hours of music. They used this data to train an AI model originally created for generating speech and piano music.

The adapted AI is able to accept new vocal recordings that aren't in the training data and create a backing track for them.

To judge its abilities, the researchers got people to listen to 800 pairs of song clips, each 10 seconds long. In each pair of clips, one had a vocal that had been given a backing track by SingSong, while the other had the same vocal with either an existing human-generated backing track that closely matched the beat and key, the original backing track or an entirely random backing track (arxiv.org/abs/2301.12662).

In 66 per cent of the trials, participants said the SingSong backing track was more "musically compatible with the vocals".

Jess Aslan at Goldsmiths, University of London says the output of the AI is convincing in terms of key, melody and harmony.

"I wouldn't say you'd release it as a finished track. It would need development, but it seems to be working in terms of coherence," she says. "The grooves it's suggesting, they work and they're interesting. And unexpected, some of them, in a good way that feels like working with another musician."

"The grooves SingSong is suggesting, they work and they're interesting, and are unexpected in a good way"

The results of SingSong are impressive in most cases, says Martyn Harry at the University of Oxford, but the technology has the potential to disrupt music production. "I have some misgivings about what this will mean culturally for us generally, as well as the implications for those musicians whose skill and musical ideas are being mimicked," he says. ▮

Matthew Sparkes

New Scientist Events

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Anil Seth
Professor of Cognitive & Computational Neuroscience (Informatics), School of Engineering and Informatics, University of Sussex

Manos Tsarikis
Professor of Psychology, Royal Holloway, University of London

Scan me to book

Medicine

Antidepressants rarely ease pain

Despite widespread use, the evidence suggests most antidepressants are poor painkillers

Clare Wilson

PEOPLE in long-term pain are often offered antidepressants when other treatments have failed, but a review has found little evidence to support using most such drugs in this way.

It is estimated that about 1 in 5 people have ongoing pain, with a variety of causes, including arthritis or nerve damage, and in various locations, including in the back or neck. However, treatment options are limited. While opioid-based medicines are effective for new-onset pain, they can be addictive when used long term. Anti-inflammatory drugs can treat pain, but can damage organs with extended use.

This may be why some doctors offer antidepressants as treatment for long-term pain, even though the drugs generally aren't licensed for such use. Some people with chronic pain are also depressed or anxious, so doctors could see the medicines as primarily helping with these conditions, but antidepressants are also thought to have a separate painkilling effect. The mechanism is unknown, but one idea is that it stems from antidepressants dampening inflammation, at least in animal tests.

It is hard to quantify the use of antidepressants for pain, but various studies give an indication. For example, one paper suggests that 1 in 10 antidepressant prescriptions in Canada were for pain, while recent figures from the UK and US suggest that chronic pain was the most common reason for people over 65 to take an antidepressant. "They have been used for pain for quite some time," says Giovanni Ferreira at the University of Sydney.

1 in 5

Estimated number of people who have ongoing pain

Ferreira and his colleagues have now conducted a detailed breakdown of the supporting evidence, analysing the results of 156 randomised trials involving more than 25,000 participants. They looked at the effectiveness of eight types of antidepressant at treating 22 pain conditions.

The team discovered there was no good evidence for the effectiveness of most of the drugs, including a class called tricyclic antidepressants, which are the most common type used for treating pain in the UK, and the selective serotonin reuptake inhibitors, which are the most common variety used in the US (*BMJ*, doi.org/grqg9f).

Only one class showed evidence of effectiveness: serotonin and norepinephrine reuptake inhibitors. But even these reduced pain only modestly, by less than 10 points on a scale of 0 to 100.

The analysis comes to different conclusions than a 2021 review by the National Institute for Health and Care Excellence (NICE), the medical guidelines body for England and Wales, which said antidepressants were the only class of medicines that doctors should consider for chronic pain, although this should only be after discussing the potential benefits and harms. The difference in conclusions may be because the latest analysis included more trials and considered each pain condition separately, says Ferreira.

Cathy Stannard at NHS Gloucestershire Integrated Care Board in Gloucester, UK, who advised on the NICE guidelines, says the new review doesn't mean antidepressants should be ruled out. "Some people will get a useful benefit and there's no way of predicting who."

But there is unlikely to be any pharmacological "magic bullet" for chronic pain, says Stannard. Doctors and people in pain should consider other options, such as specialist group exercise classes or trying to tackle difficulties like job stress or social isolation, which can amplify the impact of long-term painful conditions, she says. ▮

Materials

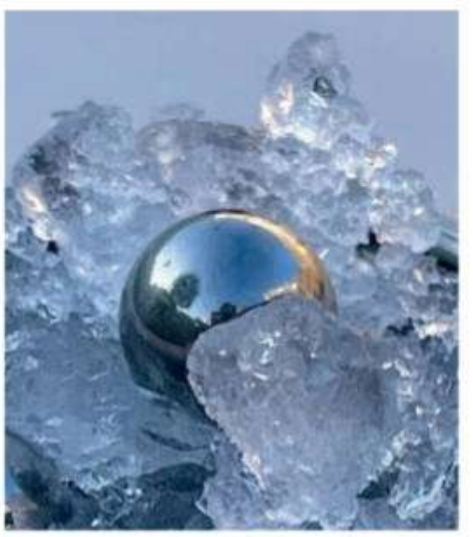
New type of ice is a strange white powder

AN ENTIRELY new form of ice has been discovered that could help unravel the mysteries of liquid water.

The new ice is amorphous, meaning it doesn't have a neatly organised crystal structure. We already knew of two types of amorphous ice – high-density and low-density – but there was a gap in the middle. However, when Christoph Salzmann at University College London and his colleagues put regular ice into a tumbler with steel ball bearings cooled to -200°C (-328°F), the shear forces produced by the jostling created medium-density amorphous ice, or MDA.

"It was one of those Friday afternoon experiments where you just do it and see what happens," says Salzmann. "Naively, you'd think nothing would happen, you'd just break the ice down into smaller bits. But to our great surprise, something did happen."

The fine white powder produced in the experiment had a density right between the other two known forms of amorphous ice, almost exactly the same density as liquid water. This led the researchers to suggest it may be water in a "glass phase", a type of matter that behaves like a liquid even at very low temperatures (*Science*, doi.org/jvj2).



The ice was made by colliding very cold steel ball bearings with regular ice

Liquid water, as mundane as it may seem, harbours mysteries once it is cooled to such low temperatures. Based on the gap between low and high-density amorphous ice, researchers have previously suggested that supercooled water may actually exist in two different liquid phases at once, with one floating atop the other, but the existence of MDA brings this idea into question. "The big question is, what is this stuff?" says Salzmann. "If we can figure out what this MDA is, then we will understand liquid water much better." ▮

Leah Crane

Farming

Putting solar panels in grazing fields is good for sheep

Christa Lesté-Lasserre

SHEEP living among rows of solar panels benefit from more nutritious food and appear to experience less heat stress compared with nearby sheep in empty fields.

Earlier research suggested that agrivoltaic farms – which combine grazing animals with solar panels – offer more efficient renewable energy at lower overhead costs, as well as reducing wildfire risks.

To study the implications of such farms for animal welfare, Emma Kampherbeek at Wageningen University in the Netherlands and her colleagues attached data loggers to the necks of 80 ewes living on 7.5 hectares of pasture on the central coast of California.

The researchers placed half the ewes in areas with a 60 per cent coverage of solar panels, and the other half in areas without any panels, in late autumn and winter, when temperatures averaged 17.5°C (63.5°F). They also sampled grasses from each grazing area to assess the amount and quality of vegetation the sheep consumed.

They found that the sheep on pasture with solar panels spent more than 70 per cent of their time under the panels and grazed 8 per cent more than those on land without solar panels. "They really liked being under the solar panels," says Kampherbeek.

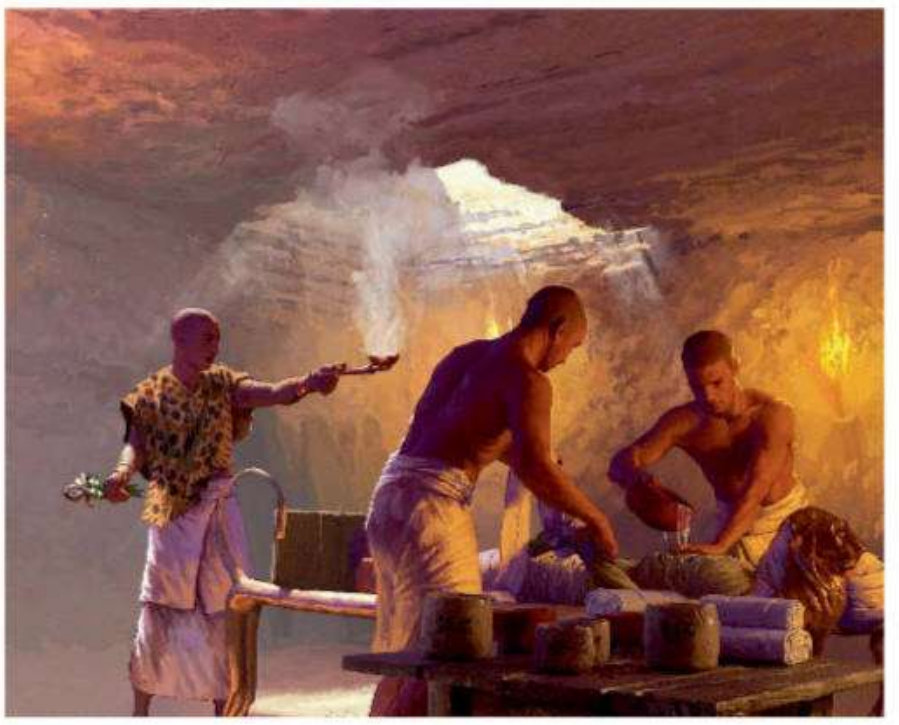
The sheep also spent 71 per cent more time lying down compared with those in open pasture and 16 per cent less time standing around idle – a behaviour that hints at poor welfare (*Applied Animal Behaviour Science*, doi.org/jvh9).

As for pasture quality, the nitrogen content was higher and carbon content lower in the vegetation in the solar panel fields, suggesting it was more nutritious and easier to digest. That might be due to less exposure to intense sunshine and to dew dripping off the panels, says Kampherbeek. ▮

Archaeology

Ancient Egyptians used exotic resins to make mummies

Michael Marshall



NIKOLA NEVENOV

Illustration of the embalming workshop at Saqqara

AN UNDERGROUND workshop found at an ancient Egyptian burial site contains ceramic vessels with traces of the substances used to make mummies. They include resins obtained from as far away as India and South-East Asia, indicating that ancient Egyptians engaged in long-distance trade.

"We could identify a large diversity of substances which were used by the embalmers," says Maxime Rageot at the University of Tübingen in Germany. "Few of them were locally available."

The workshop, dating from around 600 BC, was discovered in 2016 at Saqqara, which was the burial ground of Egyptian royalty and elites for centuries. "It was used as an elite cemetery from the very earliest moment of the Egyptian state," says Elaine Sullivan at the University of California, Santa Cruz, who wasn't involved in the study.

Close to the pyramid of Unas, archaeologists found two vertical shafts dug into the ground. One was 13 metres deep and led to the embalming workshop, while the other descended 30 metres and led to burial chambers.

It is the first Egyptian embalming workshop to be found underground, says team member Susanne Beck at the University of Tübingen. This may have been to maintain

"Many of the substances used in embalming had antibacterial and antifungal properties"

the secrecy of the process, but it also had the advantage of keeping decaying bodies cool.

In the workshop, the team found 121 beakers and bowls. Many were labelled: sometimes with instructions like "to put on his head", sometimes with names of embalming substances and sometimes with administrator titles.

The researchers chose the nine beakers and 22 bowls with the most legible labels for analysis. They studied the chemical residues left in the bowls to find out what substances had been used during embalming and mummification.

A host of substances, including plant oils, tars, resins and animal fats, were discovered. Two examples were cedar oil and heated beeswax. Many of the substances were known to be used in mummification, but some were new. One new substance was dammar, a gum-like resin obtained from trees in India and South-East Asia. The name "dammar" is a Malay word.

The team also found elemi, a pale yellow resin resembling honey that comes from trees in the rainforests of South Asia and southern Africa (*Nature*, doi.org/grqg2w).

The dammar and elemi show that Egyptian embalming drove early globalisation, says Philipp Stockhammer at Ludwig Maximilian University in Munich, Germany, another member of the team. "You really needed to transport these resins over large distances." It fits with other evidence of long-distance trade at the time.

The substances were probably transported by chains of traders. "The Egyptians don't have to be going to the eastern side of India themselves," says Sullivan.

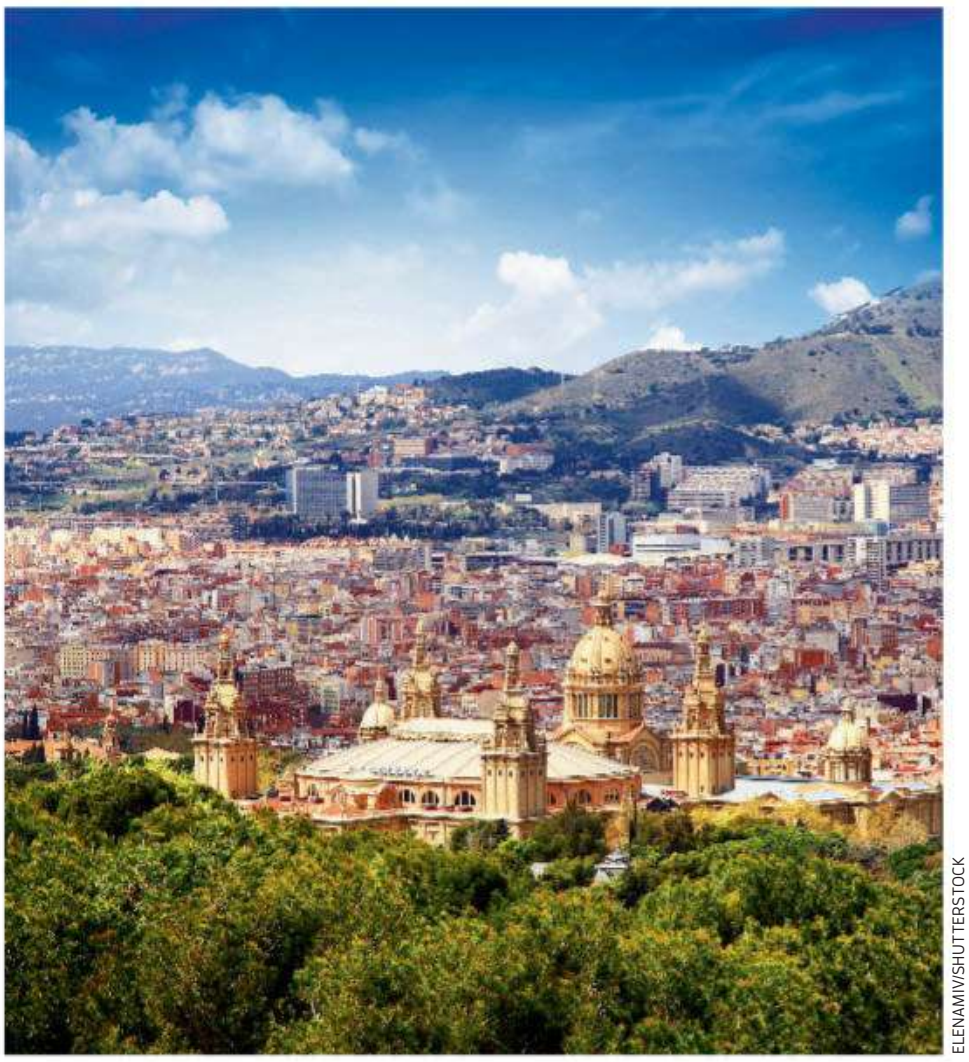
Many of the substances had antibacterial and antifungal properties, and were combined into elaborate mixtures. For Stockhammer, this complexity displays the "enormous personal knowledge that was accumulated through these centuries of experience of embalming human individuals". ▮

Archaeology

Viking invaders brought animals

THE idea that Vikings shipped horses and dogs from Scandinavia to England has been confirmed with physical evidence, in the form of animal bones found at the Heath Wood cemetery in what is now Derbyshire in the UK. It is believed to be a burial ground for the first large Viking army to travel to the country, in AD 873.

Tessi Loeffelmann at Durham University in the UK and her team analysed strontium in bone fragments already identified as being from a horse and a dog. Different geographic areas have specific ratios of the various elemental forms, or isotopes, of strontium, and this is reflected in bones. The team found a probable match with the Baltic Shield bedrock, an area including Finland, Sweden and much of Norway (*PLoS One*, doi.org/grqg5g). **Jeremy Hsu**



ELENAMIV/SHUTTERSTOCK

Psychology

Sound and motion aid time perception

MOVING your body while hearing a sound may help you perceive the passing of time more accurately.

Martin Wiener at George Mason University in Virginia and his team asked 20 people to control a robot arm until they felt a vibration. The participants then held a button down for how long they thought they had moved the arm.

Next, the participants listened to a short tone and pressed the button to indicate how long they thought the tone lasted. Finally, they controlled the arm and heard the tone at the same time, and again pressed the button.

In the test with just the robot arm, they slightly underestimated the time. For the auditory tones alone, they slightly overestimated. Participants were most accurate when receiving both inputs (*Proceedings of the Royal Society B*, doi.org/jvmx). **Alex Wilkins**

Climate change

More trees can cool cities and cut death toll in heatwaves

DOUBLING tree cover in European cities could cut the number of heat-related fatalities during summer months by nearly 40 per cent, according to a modelling study.

Average canopy tree coverage in European cities is just under 15 per cent. This is the area covered when viewed from above. Cities such as London and Barcelona (pictured) are aiming to double this to 30 per cent by 2030 and 2037, respectively.

To investigate the effect of doing this, Tamara Iungman at the Barcelona Institute for Global Health, Spain, and her team combined mortality data from 93 cities between June and August 2015 with daily temperature statistics to estimate the number of heat-related deaths over this period.

The researchers chose to study 2015 data because that is the most recent year for which European-wide statistics are available and its temperatures were typical of the current European climate.

They then modelled the impact on temperatures and mortality if tree cover in the cities increased.

Between June and August 2015, 6700 premature deaths occurred across the 93 cities due to extreme heat. Yet 2644 of these could have been avoided by increasing tree cover to 30 per cent, the results suggest.

Trees help tackle the "urban heat island effect", in which temperatures in cities surpass those in nearby rural areas because many urban surfaces absorb and retain heat. In some places, the difference between cities and rural areas can be more than 4°C (*The Lancet*, doi.org/jvmf).

As climate change accelerates, urban areas must brace themselves for more extreme heatwaves, the researchers say. Madeleine Cuff

Really brief

CHRIS J RATCLIFFE/GETTY IMAGE

England's sewage system overloaded

Sewage is regularly being released into English rivers and seas because about 80 per cent of the country's wastewater systems seem to be frequently pushed beyond capacity and can't cope with the size of the population (*Environmental Science: Water Research & Technology*, doi.org/grp7h2).

No more driverless vehicles please

Officials in San Francisco have asked for a halt to the expansion of autonomous vehicle tests across the city. The San Francisco County Transportation Authority cites incidents last year of automated taxis stopping without reason and blocking traffic, erratic driving and hampering emergency services.

Vine-like robot turns towards heat

A long, segmented robot that steers itself towards a heat source could be used to create smart hosepipes that move in the direction of a fire. It works thanks to liquid in segments on the warmer side evaporating as it gets hot, swelling and shortening that side, bending the robot (arxiv.org/abs/2301.07362).

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Comment

Too many broken hearts

Understanding a lesser-known form of broken heart syndrome could be key to protection from sudden cardiac death, says **Sian Harding**

IS IT really possible to die from a broken heart? This question often comes up in the press when someone dies suddenly following a bereavement – for example, when Debbie Reynolds died a day after her daughter, Carrie Fisher. The answer is yes, there is strong evidence to show that extreme and/or sudden emotional stress can have direct and damaging effects on the heart.

Cardiac arrest is caused by severe disturbances to the heart's rhythm. It can be triggered by highly stressful situations such as bereavement, which has led to the term broken heart syndrome. Arguments and dramatic events like natural disasters and even sporting fixtures can also be the cause. If the heart isn't shocked back into its correct rhythm, it can be rapidly fatal: this is known as sudden cardiac death.

SIMONE ROTELLA

Studies show sudden cardiac death is most usually seen in men, for reasons that aren't yet clear. It causes 25 per cent of all deaths from heart disease. But there is a less-well-known condition that is also called broken heart syndrome. This is more common in postmenopausal women (80 to 90 per cent of patients) and has a more hopeful prognosis. Could it be the key to protection from sudden cardiac death?

The first observations of this other condition were in Japan in 1990, after an earthquake. It feels and presents like a heart attack, with chest pain, but, crucially, can be spontaneously reversible. Doctors can find no evidence of a heart attack, but see a temporary loss of function of part of the heart muscle. Japanese clinicians called it takotsubo syndrome, since the peculiar shape of the heart in images reminded them of tako tsubo octopus pots. Bereavement is again a common cause, as are natural disasters.

Up to 5 per cent of people with takotsubo syndrome die within the first few days of the triggering incident, but many people recover heart function quickly with supportive treatment. Yet takotsubo syndrome is very likely to be misdiagnosed, as doctors may miss the heart paralysis unless special imaging is used. The patient, discharged without a diagnosis, is usually confused and anxious. The syndrome recurs in a significant number of people.

The difference between men and women is illustrated by one case study, in which a Chilean family were watching a football final (a well-known trigger for heart problems). Their team lost to Brazil and a huge family argument arose. The husband collapsed and was taken to hospital, where he sadly died of cardiac arrest. About an hour later, his wife was admitted to the same hospital with cardiac symptoms: she was diagnosed with takotsubo syndrome and discharged a few days later after a full recovery.

My team's research has shown that very high adrenaline levels can switch the heart into a state of temporary depression of function. When we tried to block this effect in anaesthetised rats, we were surprised to find we would trigger an irregular heart rhythm and sudden cardiac death. Because of this, we think that takotsubo syndrome may in fact be a protective mechanism, depressing the heart in the short term in order to prevent a worse outcome.

Why would more women experience takotsubo syndrome than men? The hormone oestrogen may be a key factor, as young women seem to be protected from both types of broken heart syndrome. Older women will have some oestrogen, albeit reduced levels, and we have yet to learn whether trans women with gender-affirming hormone treatment will be protected.

Better recognition of takotsubo syndrome is crucial. But even more important is understanding if and how this protective effect occurs. It could be a path to a new therapy for both types of broken heart syndrome, which would benefit everyone.

Sian Harding is emeritus professor of cardiac pharmacology at Imperial College London and author of *The Exquisite Machine*

No Planet B

Natural justice The movement to grant legal rights to nature to exist, thrive and regenerate has been bubbling under for decades, but it has just scored a big win, says **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *Mustn't Grumble: The surprising science of everyday ailments*. You can follow him @grahamlawton

Graham's week

What I'm reading
The Year of Magical Thinking *by Joan Didion*

What I'm watching
I'm looking forward to a binge on the flight home.

What I'm working on
How to pay my credit card bill after a week in New York.

This column appears monthly. Up next week: Annalee Newitz

I AM writing this from New York City, where *New Scientist* recently opened an office. I am an urban creature so I feel at home here, but green space is thin on the ground. There is Central Park but, unlike London, there are very few small patches of nature to offer respite from the pace of life in the epicentre of late-stage capitalism.

It is a little ironic, then, that New York is also one of the epicentres of a movement that could do much to challenge the hegemony of 21st-century corporations. Just up the road from here, lawyers at the City University of New York's John Jay College are putting the intellectual meat on the bones of a growing movement called Rights Of Nature, which aims to grant fundamental legal entitlements to trees, rivers, ecosystems and so on that are similar to those we enjoy as humans – to exist, flourish, thrive and regenerate. The idea has been bubbling under for decades, but recently scored a big victory at the latest round of biodiversity negotiations, with almost 200 countries signing up to an agreement that recognises that nature can have rights.

For much of recent human history, nature has been regarded as mere property, a vast repository of resources to be exploited. That philosophy has driven the environmental destruction that has pushed us into the triple planetary crises of climate change, biodiversity loss and waste and pollution. The rights of nature movement aims to end that exploitative relationship and replace it with a mutually respectful legal partnership between humans and nature.

This push was inspired by the harmonious and sustainable relationship between many Indigenous peoples and nature. It entered Western legal discourse in 1972, when Christopher Stone at the University of Southern California law school in Los Angeles published an article called "Should trees have standing? Toward legal rights for natural objects". He acknowledged that this seemed fanciful, but wrote: "I am quite seriously proposing that we give legal rights to forests, oceans, rivers and other so-called 'natural objects' in the environment – indeed, to the natural environment as a whole."

In 2006 , Stone's vision was finally realised when the town of Tamaqua, Pennsylvania, banned the dumping of toxic waste on

"For much of recent human history, nature has been regarded as mere property to be exploited"

the grounds that it was a violation of nature's rights. Until then, such activity could be stopped because it was illegal or violated a person or corporation's rights, but nature itself had no rights not to be polluted. Dozens of municipalities in other US states followed suit, and continue to do so. In December, Gig Harbor in Washington decreed its southern resident orcas have legal rights.

In 2008, Ecuador became the first national jurisdiction to recognise the rights of nature in its constitution; in 2011 those rights were tested in court over a highway project that was dumping large amounts of rubble into the Vilcabamba river. Nature won. Since then, Bolivia, New Zealand, Bangladesh, Ecuador, Brazil, Colombia, Mexico, Uganda and Panama have passed laws or amended their constitutions to recognise the rights of nature.

Such rights often succeed where regular environmental laws fail. In 2021, for example, Ecuador's supreme court called a halt to exploratory mining in a protected area of rainforest called the Los Cedros Reserve. According to environmental lawyer Hugo Echeverria at the University San Francisco de Quito, Ecuadorean environmental law allows it, but the country's highest court ruled it violated the constitution. Nature doesn't always win, but it wins more often than it used to.

The biggest victory so far came in December at the end of last year's global biodiversity negotiations in Montreal, Canada, which set out to reach a consensus on how to protect wildlife up to 2030. The agreement that eventually emerged explicitly acknowledges the rights of nature, saying that they will be an integral part of successful implementation.

Unfortunately, none of it is binding, and it is up to individual governments to implement this. But the resulting Kunming-Montreal Global Biodiversity Framework is the first international agreement to mention rights of nature. I think that makes it a watershed moment. Elizabeth Mrema, head of the UN Convention on Biological Diversity, hailed it as the biodiversity equivalent of the 2015 Paris climate agreement.

Cynics will point out that not one of the previous set of global biodiversity goals – the 20 Aichi Targets, which ran from 2010 to 2020 – was fully achieved, and that we are still on course to overshoot the Paris agreement's 1.5°C target. Cynics have a point. But let's not forget that many countries fail to fully implement the Universal Declaration of Human Rights, yet the world is still a better place because those rights exist. ▮

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JULIA RAVEY

Hot shot

Photographer Olivier Grunewald

WITH around 30 active volcanic ranges, Iceland is no stranger to lava and ash. But the eruption of Fagradalsfjall, daringly captured here by photographer Olivier Grunewald, has been one of the most memorable in recent times.

It sparked back into activity in March 2021, breaking a period of more than 800 years of volcanic dormancy in the Reykjanes region, near the capital Reykjavík. Not only did this turn into the longest-lasting eruption Iceland has seen in half a century, with its initial stages stretching over nearly half a year, its slow, effusive flow of lava (rather than volatile explosions) meant that the surrounding area was largely safe for the hundreds of thousands of visitors eager to catch a glimpse.

This magnificent image, taken in June 2021, shows Fagradalsfjall's central crater filled with lava, forming a fiery lake of liquid rock that spills down its slopes. "Volcanoes generally fascinate me by their beauty, their power and by the feeling of being in contact with the forces that created our planet," says Grunewald, who has been photographing such events for more than 25 years.

It can be dangerous work, he adds, but having an observer to keep an eye out for any risks and bringing protective equipment is sufficient to stay safe.

Despite its relatively tranquil nature, Fagradalsfjall isn't done yet. It resumed its eruption in early August 2022 (although there has been no visible activity since later that month) and volcanologists warn it is on course for a cycle of eruptions that could span several more years.

Gege Li

Editor's pick

More vegan food please, but less processed fake meat

28 January, p 13

From Erik Foxcroft, St Albans, Hertfordshire, UK

I agree that reducing the amount of meat served in schools and other institutions would be good for the planet and could lead to changes in eating habits. However, rather than just vegan burgers, sausages and fillets, wouldn't it be better to serve some of the many delicious vegan meals that can be made without highly processed products?

I am not saying that meat substitutes should never be used by these organisations, but a good vegan menu could show how the correct combinations of foods can produce well-balanced, varied and tasty meals, usually at less cost than those with fake "meat" and dairy.

However, I fear that the drive to turn this into a business opportunity for the plant-based "meat" industry will win out and good cooking with basic ingredients will be sidelined.

From Albert Beale, London, UK

It seems accepted that, if we cut our meat intake and eat more natural – rather than processed – food, we will be healthier and so will our planet. However, I don't understand the fetish for the likes of fake burgers and sausages. When I gave up eating dead flesh a long time ago, the last thing I was interested in was fake "meat".

Homework AI is here to stay, so we need to adjust

21 January, p 15

From Richard Hind, York, UK

Concerns that the ChatGPT language AI will be used by students to compose their coursework have been a topic of conversation in my college staff room for a few weeks. This is after a student showed a colleague of mine how easy it is to get this freely available AI to write good, well-commented computer code.

As with most new technology, there is an initial drive to block its use for fear it will make "cheating" easier. However, as Jeremy Hsu points out, rather than banning ChatGPT, we need to find new ways of assessing students' work.

For example, in an assignment for digital technology students, I could ask them to define some examples of security threats. But those definitions are easily copied from the internet. Instead, I ask them to analyse a case study and identify examples within it.

We should embrace new technology and teach students how to get the most from it.

The ocean mountain that just vanished from maps

28 January, p 46

From Roger Morgan, London, UK

I read your article on the power of huge marine avalanches to move massive amounts of material and reshape the ocean floor. I would like to draw your attention to the Pactolus bank off Cape Horn, which has long been a puzzle. Found in 1885, this seamount is thought to no longer exist. Perhaps it was all down to one of these events?

Not convinced by merits of human waste as fertiliser

28 January, p 17

From Guy Inchbald, Upton upon Severn, Worcestershire, UK

The fear of ingesting pathogens via use of human-waste fertilisers parallels the bovine spongiform encephalopathy (BSE) problem. In that case, material from the brains of slaughtered cows was spread to other cattle via its use in processed feeds. It was impractical to ensure adequate heat-processing of the waste meat and the practice was later banned, but not before a consequent condition called variant Creutzfeldt-Jakob disease (vCJD) emerged in people due to infected meat. Is it really easier to ensure adequate processing of human waste?

Ready to greet my sperm donation offspring

28 January, p 14

Name and address withheld

I enjoyed your article on sperm and egg donor anonymity, as did my son. Five or six of the 3691 people who will become eligible to contact their donor in the UK in 2035 are my biological offspring and his biological half siblings.

We await any contact in a positive way, but will be careful not to undermine the relationships of donor-conceived people and their real parents – the ones who love them and look after them.

On the progress in unravelling depression

21 January, p 38

From Pamela Manfield, The Narth, Monmouthshire, UK

Your article on depression was fascinating. It is great to know that so many advances are being made. Another approach is worth a mention: gardening. Several mental health charities are now using it to improve well-being.

Communal gardening seems to be especially valuable. Social mixing, the achievement of taking produce home to family and friends, as well as being out in the open air and in touch with wildlife – all of these factors make vast differences.

From Carl Zetie, Raleigh, North Carolina, US

As suggested, there may never be a unified theory of depression. The clinical successes and failures of a variety of different treatments may mean that more than one hypothesis is true, and what we now call depression is in fact a collection of different conditions sharing a cluster of similar symptoms.

Much like cancer has come to be recognised as a number of distinct but related conditions, the same might be true of depression.

Tune in to the Echo of Eternity if you dare

31 December 2022, p 46

From Patrick Gaydecki, professor of digital signal processing, University of Manchester, UK

Your feature on the use of sonification to reveal the sounds of space was intriguing. A few years ago, my colleagues and I applied the same technique to listen to the cosmic microwave background. This was achieved by downshifting its radio spectrum into the audible range and using this to filter the wideband random noise that is ubiquitous in nature. The sound was unearthly and frankly a little unsettling. We named it the Echo of Eternity.

Are eels the strangest creatures in the world?

21 January, p 42

From Chris Hall, Earley, Berkshire, UK

Your article on the European eel is a fascinating description of one of the world's most unusual animals.

For most species, you can appreciate the Darwinian logic behind each of their features: the acute hearing and nimble legs of a deer enable it to escape predators, for example. But what Darwinian forces have driven the evolution of this eel?

Why not reproduce in a local river, rather than taking a 12,000-kilometre round journey? Why wait decades before making that trip, when there is always the danger of being eaten or dying of a disease in the meantime? ▮

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The art of remembering

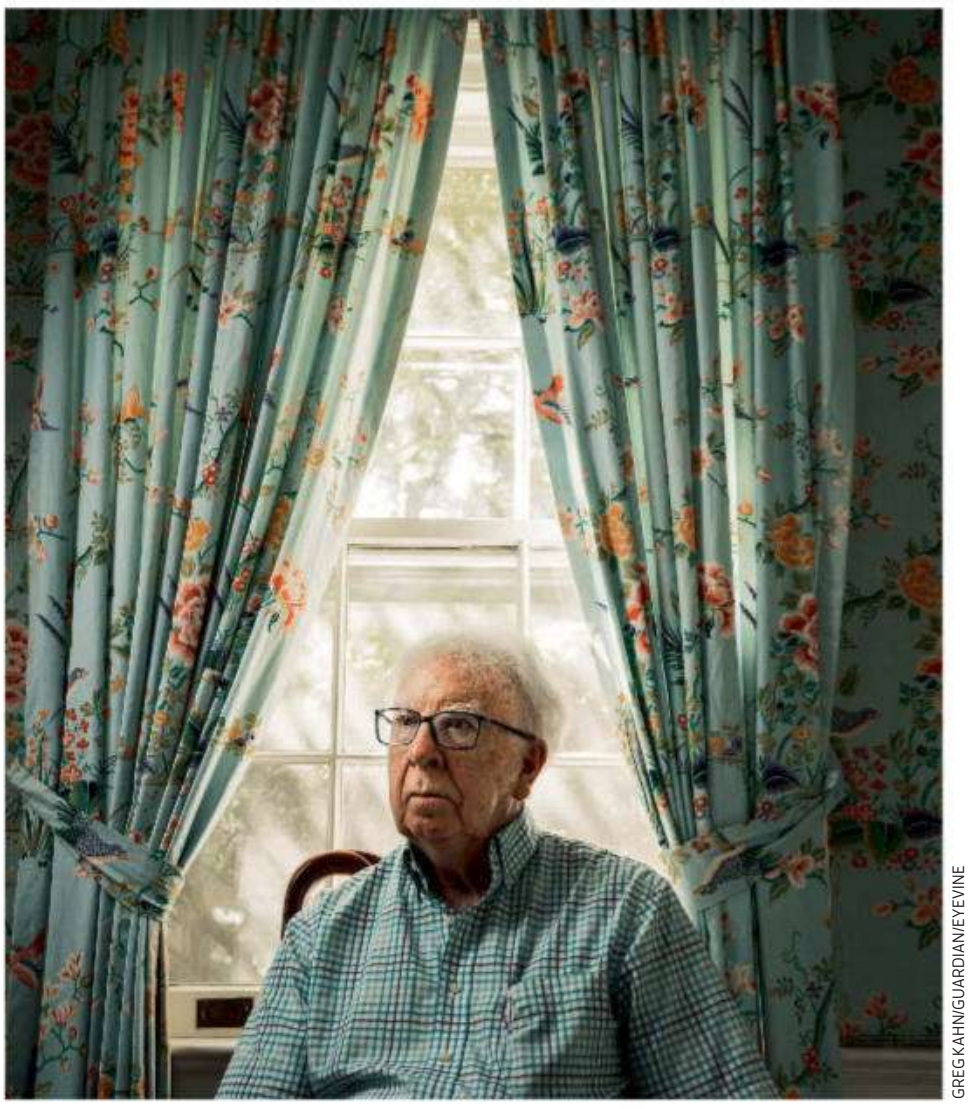
If you want to strengthen your mind, a new compendium exploring the mechanics of memory may be the place to start, finds **Alex Wilkins**

Book

The Complete Guide to Memory

Richard Restak

Penguin Life



GREG KAHN/GUARDIAN/EYEVINE

Richard Restak (left) uses case study and anecdote to explain memory

IT IS all too easy to forget how much we rely on our memory and how quickly things can go south when it falters. Although the march towards forgetfulness is often presented as a foregone conclusion, it doesn't have to be that way, writes Richard Restak in *The Complete Guide to Memory,* a short but comprehensive compendium of everything we know about memory and how we might improve it.

So-called brain training has been in vogue for decades in the form of sudoku puzzles or apps that promise to help you defy the cognitive decline of ageing, but there is little evidence for this.

Despite his book's subtitle – *The science of strengthening your mind* – Restak's gambit is slightly different. He is a neuroscientist, author of more than 20 books on the human brain, and with decades of experience of patients with memory problems. Here he argues that by performing certain tasks to boost your memory, other mental faculties that rely on it will improve and you might ease the impact of old age.

Of course, memory isn't one thing, but an interconnected series of brain structures and processes that interact with stimuli and consciousness in myriad ways. To understand how to improve it, an understanding of these processes is helpful, so Restak devotes a sizeable chunk of this book to teasing out the nuances of memory.

This includes episodic, semantic and procedural memory, how working and long-term memory differ, and how these are, in turn, formed from different stimuli, such as internal and external speech or visual information. It can feel like a whirlwind tour, and

"The main way to improve all forms of memory is to actively practise certain techniques"

unless you take Restak's advice to be attentive and intentional about remembering, the neuroscience can wash over you.

But understanding how different kinds of memories are made and stored does help make sense of the sections that follow, on how our brains use memory in daily life and what happens when those processes go wrong.

The book is at its most enjoyable when Restak blends case study and personal anecdote to explore memory and what happens when faculties falter. This is reminiscent at times of neurologist Oliver Sacks's curious case studies.

Somewhat distressingly, the chapter devoted to memory's malfunctions is almost five times as long as the chapter that describes it working as intended – but, apart from rare brain injuries or traumatic events, these cognitive vulnerabilities are apparently instructive.

For instance, knowing that advertisers and political campaigners tend to recycle and repeat the same catchphrases to evoke a sense of familiarity, and so prime you to remember them, could fortify you against manipulation in the future – or encourage you to use those same repetitious techniques for things you would like to remember.

The main way to improve all forms of memory, writes Restak, is to actively practise certain techniques, ideally daily. Some are as simple as attending to things more closely to expand long-term memory, while others are more involved, such as exercises and games that include memorising sequences of cards or numbers to boost working memory.

For all its emphasis on brain structure, the guide can feel frustratingly unstructured. Some curiosities, like the brain's tendency to more easily recall interrupted tasks (the Zeigarnik effect) or that you remember things better when you see them on large screens, seem random and underexplored, with only a few paragraphs devoted to each and little about how you should incorporate them into your life.

Then there are its more eye-catching claims – for example, that memory exercises could help prevent memory decline in Alzheimer's disease. These rely too much on Restak's clinical experience and suffer from a lack of balanced discussion, essential for a book that has "avoid memory loss" on the cover and mentions Alzheimer's on the first page.

Despite the jury being out on its anti-dementia credentials, I did find a few weeks of the daily memory exercises led to a small boost in my recall and made me feel more present. Whether I will still remember Restak's advice in a year's time remains to be seen.

Real life on Mars

Living on Mars will take enormous work, but an urban planner is already on the case, discovers **Chris Stokel-Walker**

Book

The First City on Mars
Justin Hollander
Springer

SPACE travel holds a mystique for humanity that few other areas of exploration do, and, beyond the moon, Mars is seen as the next step.

The Red Planet has come to signify opportunity in our era of polycrises. In fact, Mars has become a fixation for many, including space entrepreneur and Twitter owner Elon Musk. His vision of the future includes sending SpaceX rockets full of colonisers to Mars by 2050.

But can we really set up a new civilisation on a distant planet? Just how difficult this will be is made all too clear in a new book by Justin Hollander, an urban planner at Tufts University in Massachusetts.

***The First City on Mars: An urban planner's guide to settling the Red Planet* is a bit of an odd proposition: at first it seems like an academic book, but it is very readable and has a cover that looks like it belongs on a 1960s science-fiction novella.**

Hollander is a serious planner, however, and over 12 chapters and scores of subsections he sets out what we are up against if we want to live on Mars. Luckily, aliens aren't on his list.

Hollander outlines how, in the 1960s, the Mariner 4 mission to Mars sent back 21 images of the planet's surface. Unlike sci-fi of the time, which imagined a planet with civilisations and networks of canals, the barren landscapes it showed revealed challenges of an entirely different nature. Now, the James Webb Space Telescope is giving us even more detail.

So, arriving on Mars, there will be lots of work to get done. Hollander's planned conurbation, which he calls Aleph (the first letter of the Hebrew alphabet and the early letter from which the Greeks derived their "alpha"), is sited at Utopia Planitia. This is a large plain within Utopia, thought to be the largest impact basin on Mars and the site from which the Viking 2 lander began its exploration of the Red Planet in 1976. It can't be a coincidence that the flagship craft of several *Star Trek* series were constructed in shipyards orbiting this location.

Of course, the story will be brutally different for the colonisers. "The first city on Mars will be largely underground," writes Hollander, facing up to the reality of harmful radiation at the planet's surface.

Hollander envisions Aleph as having three sunken structures for living and working, each roughly 100 metres across and covered by a dome. This cluster would form a triangle around a communications and life-support hub.

To the north, there would be a dozen more golf ball-like domes to shield vehicle storage, greenhouses, mining hubs and more from the radiation. Aleph's citizens could shuttle around the city using rover paths on the surface, though traffic is presumably expected to be light.

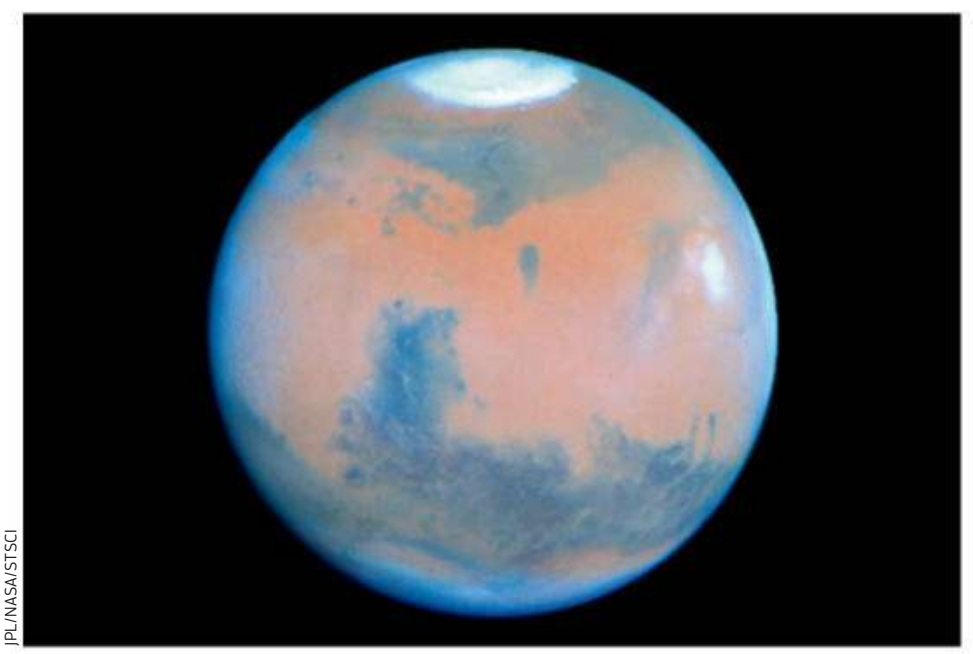
Planning pragmatism and scepticism may explain why Hollander keeps highlighting the enormous challenges involved in getting to and then safely inhabiting the Red Planet. He stresses how much the idea remains a dream by comparing it with the effort required to support life on the International Space Station, which orbits 400 kilometres above Earth's surface. Around 2500 square metres of solar panels pointed directly at the sun are needed to power the station, on which up to 13 people can live in a space the size of a UK football field.

Compared with the ISS, the idea of inhabiting Mars any time soon seems rather far-fetched. Hollander admits that "the first streets may be decades from being laid out", but this hasn't stopped several governments in richer countries from "preparing for a real, long-term human presence on Mars".

Such a move would be a giant leap for humankind – still, in writing this book, Hollander is banking on us having heard that once before. ▮

Chris Stokel-Walker is a technology writer based in Newcastle, UK

Despite the huge challenges, Earth's richer countries are making real plans to colonise Mars



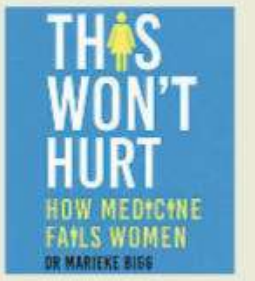
JPL/NASA/STSCI

Don't miss

TOP; DISNEY

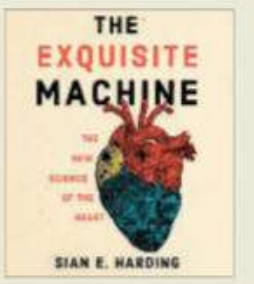
Watch

Ant-Man and the Wasp: Quantumania stars Paul Rudd (above) as petty thief-turned-Avenger Scott Lang in a new Marvel movie. Set in the Quantum Realm, Lang faces Kang the Conqueror. On general release 17 February.



Read

This Won't Hurt says Marieke Bigg, tongue firmly in cheek, as she explains how medicine fails women, from research to diagnosis and treatment. Today's landscape, she argues, was designed for men. On sale from 16 February.



Visit

Unlocking the mysteries of the heart is a talk by Sian Harding based on her book *The Exquisite Machine*. It explores new cardiac research (see comment, page 25). At the Royal Institution, London, on 13 February, 7pm GMT.

The games column

Meet your heroes In *Marvel's Midnight Suns*, you are in charge of a team of superheroes who fight villains but also hang out. Who wouldn't want to go fishing with Spider-Man or play video games with Wolverine, asks **Jacob Aron**

Jacob Aron is *New Scientist*'s news editor. Follow him on Twitter @jjaron

2K GAMES

Try explaining Doctor Strange's powers in terms of science

WHILE we wait for a rash of new games to arrive (see my previous column), I have been mopping up a few from last year that I hadn't yet managed to finish.

The one that has been occupying most of my time is *Marvel's Midnight Suns,* which puts you in charge of a team of famous superheroes. You play as a new character called Hunter (you can design their look yourself), a long-dead mystical hero destined to defeat an ancient demonic evil.

The game is in two parts that complement each other. In the first, you go on missions against a variety of villains with a team of three heroes, each of whom has a range of abilities that appear on digital playing cards. You control your team using these cards to defeat enemies and achieve objectives, such as capturing resources or destroying vehicles, and it is very satisfying to pick just the right combination of cards to unleash your superheroic might.

The second part is entirely different. It takes place in Hunter's home base, a pocket dimension called the Abbey where you and the other heroes can train, research enemies and so on.

But here is where it gets weird: there is also a social element, which means you can join a book club run by the vampire hunter Blade or even go fishing with Spider-Man, both in an effort to deepen your relationships. All of this feeds back into the combat part of the game, as a higher friendship score unlocks new cards and abilities.

"The tension between magic and science is a theme that *Midnight Suns* mines in an interesting way"

Now, I will admit you may be thinking that a game about fighting demons with magic doesn't sound the most suitable choice for *New Scientist* to review, but hear me out. While the game draws on the original Marvel comics rather than connecting to the pop culture-dominating Marvel Cinematic Universe (MCU), it clearly takes inspiration from it.

If you cast your mind back to early films of the MCU (*Iron Man*, *The Incredible Hulk* and *Thor*), they were at great pains to explain any fantastical elements as actually grounded in science. That is why Thor isn't a literal god with a magic hammer, he is just an alien whose sufficiently advanced technology is indistinguishable from magic.

Later films have been much happier to embrace actual magic as the source of some of their heroes' powers (it is hard to have a scientific explanation for Doctor Strange, for example), but this tension between magic and science still remains, and it is a theme that *Midnight Suns* mines in an interesting way.

Hunter's team is roughly split between science-based heroes, such as Iron Man, Spider-Man and Captain America (essentially the Avengers), and the more magic-based heroes, including Doctor Strange and lesser-known ones, like Ghost Rider and Magik. The science-based heroes find it frustrating when they aren't fully equipped to tackle the demonic foes they face, and Iron Man in particular is freaked out at having to work in the Abbey, where the power for his mechanical tinkering comes from a demonic forge held in check by Doctor Strange.

This version of Iron Man is quite far from Robert Downey Jr.'s carefree playboy depiction, and it is refreshing to see a new take on some of these characters, where they realise that they don't have all the answers. The social side of the game also means you can take the time to talk to them and understand what makes them tick, or even play video games with Wolverine, because why not? ▮

Game

Marvel's Midnight Suns

Firaxis Games

PC, PlayStation 4 and 5, Xbox One and Series S/X, Nintendo Switch

Jacob also recommends...

Games

XCOM2

Firaxis Games

PC, PlayStation 4, Xbox One, Nintendo Switch

This earlier Firaxis game focuses more on combat than on making friends, as you lead a band of rebels against an alien invasion.

Mass Effect

Bioware

PC, PlayStation 3 and 4, Xbox 360 and One

Midnight Suns *owes more than a little to this classic sci-fi role playing game, in which you build your crew, hang out together and save the universe.*

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THE 2000-WATT CHALLENGE
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9400 kWh
I UNPLUGGED EVERYTHING IN THE APARTMENT THAT I WASN'T USING.
I AIR-DRIED MY WASHING IN THE STAIRWELL.
I TOOK SHORTER SHOWERS.
CAN I DO IT IN UNDER 3 MINS?
0:36
I BOUGHT MORE GROCERIES FROM THE FARMERS MARKET AND BIKED WHEN THE WEATHER PERMITTED.

JASON FORD

The 2000-watt challenge

In theory, you can live a good life on a fraction of the energy you currently use. **James Dinneen** takes up the challenge

THE first thing I did was turn off the lights. Then I unplugged everything. On reflection, I reconnected my fridge. Next, I made a list of all the other ways I consume energy. Gas-powered boilers heat my apartment and water. I cook on a gas stove. I take the New York City subway to work. For longer trips, I drive or hail a ride, and I fly. Then there's the fridge, washing machine and dryer, elevators, a computer, phone, even my toothbrush. Anything I buy that requires energy to make and transport also counts. So does the food I consume or throw away. Nearly everything I do requires energy.

Next, I used an online calculator – once I got the Wi-Fi back on – to estimate my total energy use. In the US, each person consumes energy at a rate of 8600 watts on average. I didn't think my lifestyle was particularly extravagant, so I was surprised to find I use even more than that.

Energy is a hot topic right now. Rocketing fuel prices precipitated by Russia's invasion of Ukraine and the transition to renewable sources to limit global warming have focused people and governments on reducing consumption. With this in mind, I wanted to see whether I could drastically cut my energy use. I had read that, in the 1990s, Swiss researchers calculated that just 2000 watts per person would be enough for everyone to live sustainably and still have a good quality of life. So that became my target. This was the first day of a personal, month-long "2000-watt challenge". Clearly, I had a long way to go.

A watt is a measure of power or, put another way, the rate of energy transfer (see "What's watt", page 38). For much of human history, people consumed little more energy than that which was embodied in the food they ate. On a per person basis, "that's perhaps 90 watts on average", says Sascha Nick at the Swiss Federal Institute of Technology Lausanne. Fuel for cooking and heating added more watts, as did animal power for agriculture and transport: 1 horsepower, a unit coined by inventor James Watt (after whom the watt is named) to promote his improved steam engine, is equivalent to 746 watts. Complex societies with construction, metalworking and pottery added a few hundred more. "The Roman Empire had a consumption of perhaps 500 watts," says Nick. "And it didn't use electricity at all."

Today, industrialised societies use vastly more energy, exploiting mainly fossil fuels to power the global economy. The average total, or "primary", rate of energy consumption per person is highest in Iceland coming in at 17,000 watts in 2021. The US, at 8600 watts, was number 11. By comparison, per-person rate of energy use was around 4200 watts on average in the European Union, 3400 watts in China and 3300 watts in the UK. But there is massive inequality globally: people in India used 800 watts and in Bangladesh they used just 310 watts. The International Energy Agency estimates that more than 2.5 billion people worldwide lack access to enough energy for basic needs such as cooking and cooling.

The unprecedented increase in energy consumption in high-income countries – and the environmental consequences it entails – has prompted energy researchers to ask: when energy becomes available far beyond the minimum needed, what is sufficient to live well? It is a question worthy of Socrates. What constitutes enough? What is a good life? So it is hardly surprising that there is no consensus among economists or energy experts. "I'm not confident yet to define an actual threshold of sufficiency of material consumption," says energy researcher Narasimha Rao at Yale University. "But I know it's well below the maximum that you see in many countries."

Two-thousand watts is one answer. Back in the 1990s, it was the amount of energy available to each person on Earth if all the energy produced was divided equally. Based on this and on studies that found diminishing returns to quality of life beyond this level of consumption, researchers at the Swiss Federal Institute of Technology Zürich calculated that using energy at a rate of 2000 watts – equivalent to using 48 kilowatt-hours per day – was sufficient for each person in Switzerland to consume without sacrificing their enviably high standards of living. The team also concluded that aiming for the ambitious but ›

feasible 2000-watt target would be a means of helping Switzerland reduce its greenhouse gas emissions (see "Emission critical", page 39).

I first read about the 2000-watt society in Kim Stanley Robinson's novel *The Ministry for the Future*, which was published in 2020. From a not-too-distant future where Switzerland has achieved this goal, a chipper character points to the country as an example of the wisdom of using less: "It took paying attention to energy use, but the resulting life was by no means a form of suffering; it was even reported to feel more stylish and meaningful to those who undertook the experiment." This notion that living at 2000 watts wouldn't be so hard stayed with me and, when the price of energy jumped last year, I thought I would try it for myself.

My own energy audit

The first thing to do was to estimate my total usage – which anyone can do with an online calculator. This also helped me see how my energy usage breaks down into different areas. Transportation accounted for about half, due almost entirely to flying. Food and other things I bought accounted for about a third, while home heating and electricity made up the rest. Probably because I live in a small apartment, this footprint was a bit different from the average US resident whose living and office space tends to make up the largest proportion of energy use, followed by transportation (especially by car), food and consumer items, electricity and finally their share of public infrastructure. In Europe, living and office space also make up the greatest share on average, but food and consumer items tend to use more energy than transportation.

In total, my rate of energy use was running at 9400 watts. I was definitely going to need help if I were to have any hope of meeting the challenge.

First, I consulted Amory Lovins, a professor at Stanford University in California and founder of a sustainability think tank called the Rocky Mountain Institute. He is perhaps the world's best-known energy efficiency guru and he walks the talk. He lives in a beautiful home he built in Colorado that features every energy efficiency hack imaginable. "It's actually 6000-year-old passive Chinese solar architecture," says Lovins. "I just updated the technologies." His house has a rooftop tank that heats water with sunlight. Multi-paned windows improve insulation. The property was built facing south to get more heat from the sun, using materials selected for their small energy footprint. A greenhouse serves to both help heat the house and grow a crop of banana plants. All this means Lovins maintains a high standard of living while his home generates enough power to charge his electric vehicles and export some electricity to the grid.

With the right technology, the rate of energy use needed to maintain a high standard of living is "probably under 2 kilowatts", says Lovins, maybe even as low as 1000 watts. However, for most people, such technologies aren't in reach yet. What's more, those that are available don't necessarily reduce our energy usage in the long term. That is because of the rebound effect, a well-known phenomenon by which people use the savings gained from efficiency to consume more. For example, as car engines have become more efficient, we have bought larger cars that require more fuel to power them.

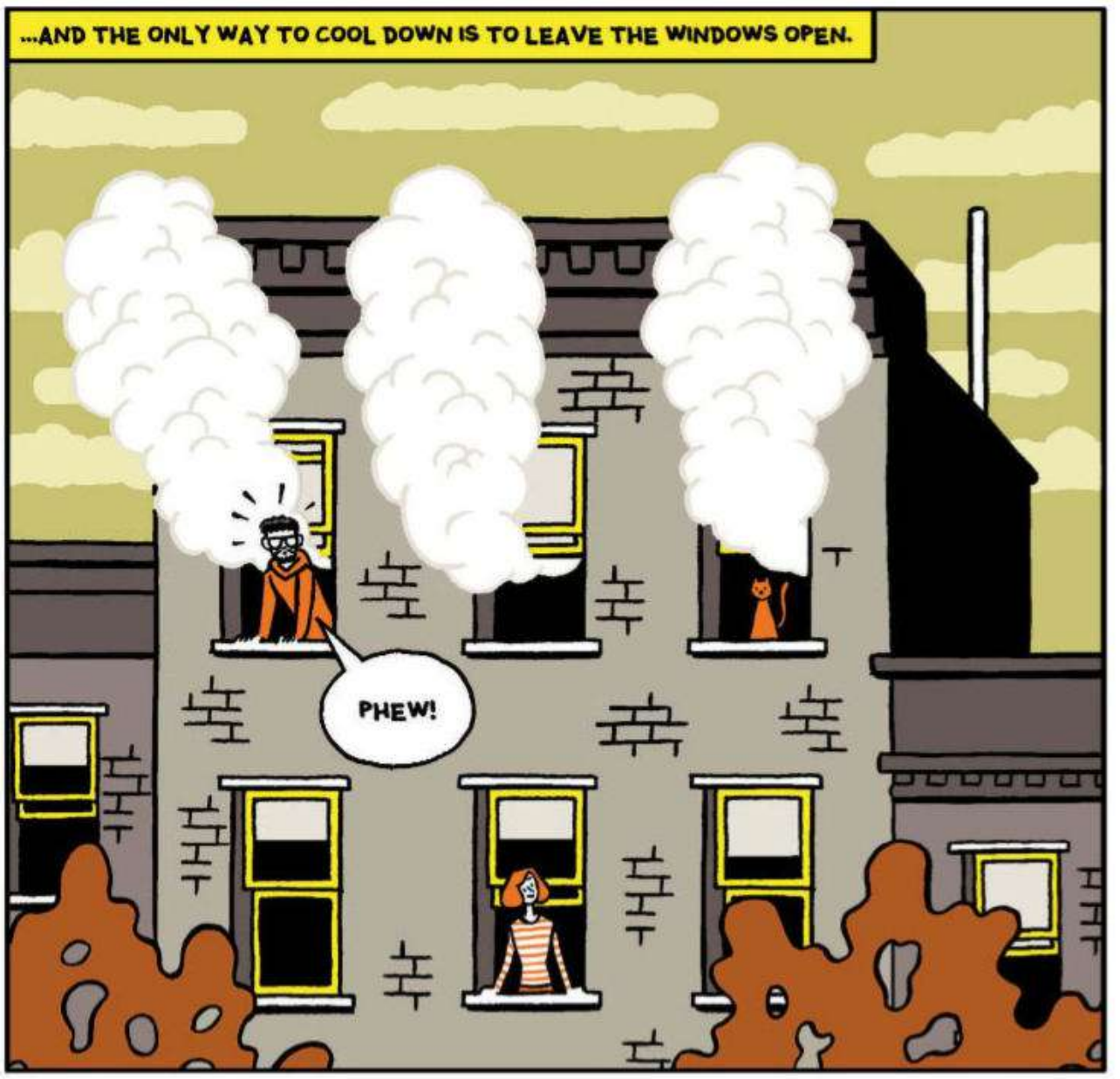
Besides, adopting energy efficient technologies wasn't going to help with my hastily organised 2000-watt challenge because I had just a month and no budget. So I decided to focus on the other approach to reducing energy consumption: altering my behaviour.

There were practical changes I could make straight away. For instance, I made sure nothing in my apartment was on or plugged in unless someone was using it. I air-dried clothes in the stairwell instead of using the dryer. I shared data from my electricity meter with a company called OhmConnect, which sent me a text when electrical demand was high and gave me an incentive to use less – in the form of "watt points" I could exchange for prizes – if I cut my use during that period. I found I could temporarily save around 150 watts by unplugging the fridge for an hour without opening the door.

All this certainly helped me save energy. But at best I had only reduced my rate of usage by around 1000 watts. In fact, the online calculator had shown that electricity accounted for only about 5 per cent of my total, so I could have used none and still ended up far above 2000 watts. I would need to make other changes. So I took shorter showers and

What's watt?

The watt is the unit of power used to describe the rate at which energy flows: 1 watt is equivalent to 1 joule per second. A 20-watt light bulb left on for an hour uses 20-watt-hours. Your electricity bill will show how many kilowatt-hours you have used (1 kilowatt is 1000 watts). Dividing that by the number of hours during the billing period will give your average continuous supply of electricity in kilowatts. The 2000-watt target – which can also be seen as 48 kilowatt-hours per day – refers not just to electricity, but to your total average primary energy consumption. In other words, it includes all sources of energy (things like gas, wind and wood), any energy used to produce those sources and the energy lost due to inefficiencies of conversion and transmission. To meet the challenge, this must not exceed an average of 2 kilowatts.



Emission critical

Different energy sources produce different levels of greenhouse gas emissions. Coal burned to generate electricity creates more than burning natural gas, for example. And solar creates none. And there are also sources of emissions unrelated to energy such as food rotting in landfills. In the 1990s, when Swiss researchers first envisioned a 2000-watt society, it included a target for emissions equivalent to 1 tonne of carbon dioxide per person. Back then, there was more concern about running out of oil than about climate change. However, that target was revised to net zero in 2015, following the Paris Agreement, which committed countries to limiting global warming to well below 2°C above pre-industrial levels. To try to achieve this, Switzerland has aggressively invested in renewable energy in parallel with its work on energy efficiency. Since 2000, emissions resulting directly from energy use have decreased from 8.5 to 5.6 tonnes per person. However, emissions associated with imported goods have increased during that period. The emissions target is still much more challenging than the energy target.

used cold water to wash dishes. I continued to bike whenever the weather permitted and took the subway when it didn't. I bought more of my groceries from the farmers' market down the street than from the supermarket. And I ate more vegetarian meals.

All this only took me down to 5700 watts according to the calculator, with many of those savings coming from not flying. One big problem was the aging gas boiler heating my poorly insulated 120-year-old apartment. It was a major cause of my surprisingly high energy use – but also beyond my control. As in many old buildings in New York, my radiators are controlled by my landlord, who also lives in the building and likes it hot. In winter, the only way to cool down is to leave windows open. In summer, cooling requires inefficient window air conditioners. Reducing those watts would require retrofitting the building with energy efficient heat pumps and improving the insulation. But as a renter, I couldn't do that, even if I had the means.

The point here isn't to complain about my radiators. What the story illustrates is that it is very difficult to live at 2000 watts unless you live in a 2000-watt society. "You start to get to a point that the society around you, the environment you live in, prevents you going beyond," says Stephan Tanner, an architect who specialises in efficient buildings at the design firm Intep and a long-time proponent of making the US a 2000-watt society. What those limits are depends largely on where you live and how much money you have. For me, living in New York, walking or taking public transport is relatively easy. But in many other places, especially elsewhere in the US, people have no choice but to drive to work or to the grocery store. The changes required to address that aren't something that an individual can manage.

"It is very difficult to live at 2000 watts unless you live in a 2000-watt society"

"Much of what we do in society and life is a matter of how we organise society," says Nick. He has been consuming 2000 watts or less for more than a decade, but living in Switzerland helps. In 2017, the government there committed to achieving a 2000-watt society by 2050. To that end, Swiss cities are boosting public transport infrastructure and making car use less attractive. They have also built energy efficient hospitals and retirement homes. From an average of about 6000 watts in 2000, per-person rate of energy usage in Switzerland is now 4030 watts.

Beyond Switzerland, few other societies have adopted the 2000-watt target. But countries are focusing more on reducing demand for energy. Policies like the Inflation Reduction Act in the US, REPowerEU in the European Union and Japan's Green Transformation have put hundreds of billions of dollars towards energy efficiency measures, such as retrofitting buildings and promoting the use of electric vehicles. Countries have rolled out energy awareness campaigns too, ›

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Six ways to use less energy

TURN DOWN THE THERMOSTAT:
We all have to keep warm, but staying a few degrees colder can save up to 10 per cent of energy for heating. Potential savings depend on many factors, such as the weather where you live.

USE LESS HOT WATER:
Heating water accounts for around 20 per cent of home energy use on average. Reduce this by using cold water to wash clothes, making sure the dishwasher is full and taking shorter showers.

WALK, CYCLE AND USE PUBLIC TRANSPORT:
One study found that public transportation use in the US saved the equivalent of 4.2 billion gallons of petrol in a year.

USE EFFICIENT APPLIANCES:
Electric induction stoves are about three times more energy efficient than gas stoves. Search for labels on appliances that rate their efficiency.

EAT MORE VEGETABLES, PREFERABLY LOCALLY GROWN:
Vegetarian diets use approximately a quarter less energy than diets that include meat.

RETROFIT YOUR HOME:
Improving home insulation and using an energy efficient heat pump rather than gas or oil heating are big investments, but making them can cut energy use by more than 40 per cent, depending on where you live.

including It All Adds Up in the UK.

The fuel crisis is one motivation. "That might be what will start to expand our consciousness," says Christina Hoicka at the University of Victoria in Canada. Improved energy efficiency has already paid off: the International Energy Agency estimates that such enhancements saved at least $680 billion in energy costs among its member countries in 2022. Using less energy also cuts greenhouse gas emissions directly and makes decarbonisation easier to achieve. "If we electrify everything, we have to massively increase the size of our renewable energy system," says Hoicka. That will be far easier if there is less demand. One widely cited study found that reducing energy demand through efficiency and changes like urbanisation and digitalisation could limit global warming to 1.5°C without the need for unproven carbon capture and storage technologies and without sacrificing economic growth in higher or lower-income countries.

Could do better

As for my own humble 2000-watt challenge, I regret to say that it failed miserably, at least by its main measure. For now, inefficient buildings and infrastructure make it very difficult to consume at a rate of 2000 watts and maintain a high standard of living in the US without making a major investment in energy efficiency – and it isn't much easier elsewhere.

But I did learn a lot (see "Six ways to use less energy", left). And I don't plan to stop trying to achieve 2000 watts just because this challenge is over. For instance, it is clearer to me that decisions about what I eat and how I get around are much more important than how long I leave the lights on. And next time I choose somewhere to live, I will be thinking more about how it is heated, how well it is insulated and how energy efficient the appliances are. That way, I can focus more on small actions that produce sizeable energy-efficiency gains.

This experience has left me more mindful about where the energy I use is coming from too. I feel less disconnected from the infrastructure and industrial activities that support my way of life. I am also more cognisant of the overabundance of energy available to me – and the unfairness that so many people don't have enough. "Enough should be a human right, a floor below which no one can fall; also a ceiling above which no one can rise," according to Robinson's character from the future. "Enough is as good as a feast – or better." ▮

James Dinneen is an environment reporter for *New Scientist* based in New York

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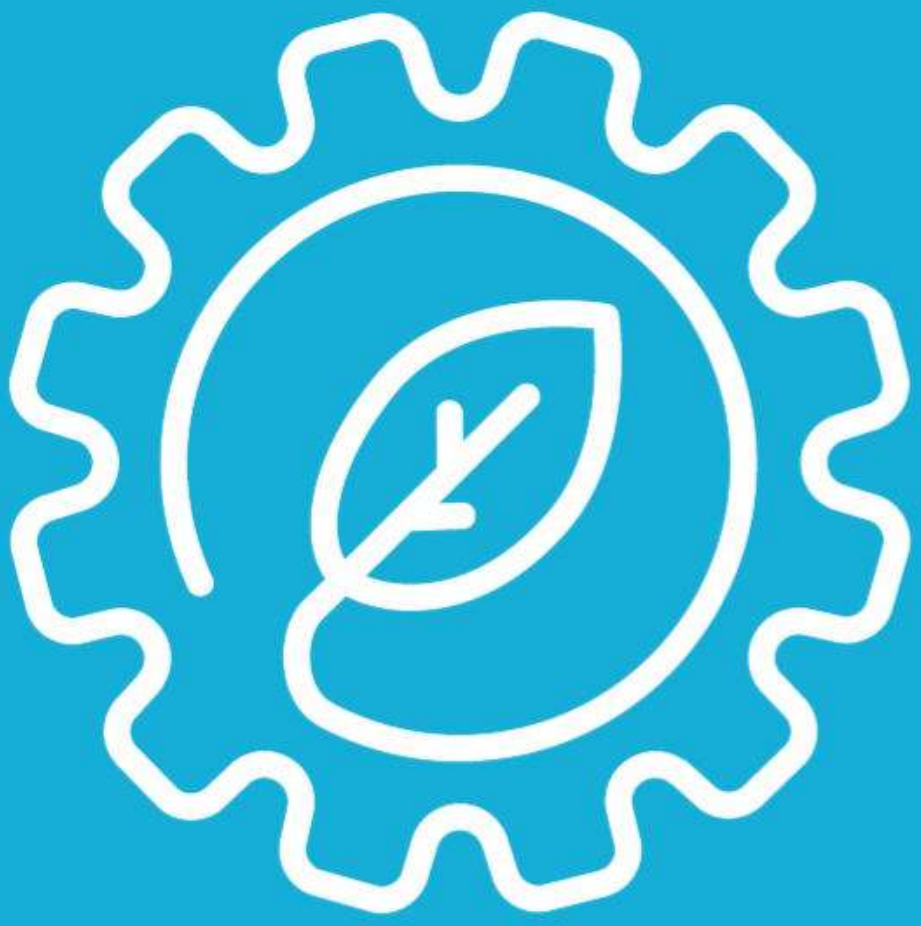

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Paranoid, me?

Psychologists are forging a new understanding of why we are susceptible to the idea that other people are out to get us – and what we can do to keep it in check. **Kayt Sukel** reports

JAMES TILLEY MATTHEWS feared the Air Loom Gang. In 1797, he claimed that this mysterious group of villains could control his thoughts using a kite and manipulate "the magnetic fluid" to force him to smile. The gang was a figment of his imagination, but Matthews's insistence that he was being persecuted saw him admitted to a psychiatric hospital in London. Today, many researchers suspect he had schizophrenia. In the 200 years since, the broad assumption has been that paranoia of the kind Matthews experienced is a symptom of a severe mental health condition. But attitudes are now changing.

Research over the past 20 years has revealed that paranoia isn't restricted to a subset of the people who have been diagnosed with schizophrenia or similar conditions. Some researchers argue there is, in fact, a paranoia spectrum, and perhaps 1 in 6 of us may fall somewhere along it. Even more remarkably, the number of people prone to paranoid thoughts rose as covid-19 spread across the world.

Such discoveries have prompted psychologists to take a fresh look at paranoia, including its overlap with conspiracy theories such as QAnon. The research has led to the intriguing idea that mild paranoia, far from being undesirable, may be an evolved condition that worked to the advantage of our hominin ancestors – and still benefits us today. The work has also brought us closer to working out why we might end up on the paranoia spectrum and, if we do, identified some simple changes we could make to our lives to protect ourselves from going too far.

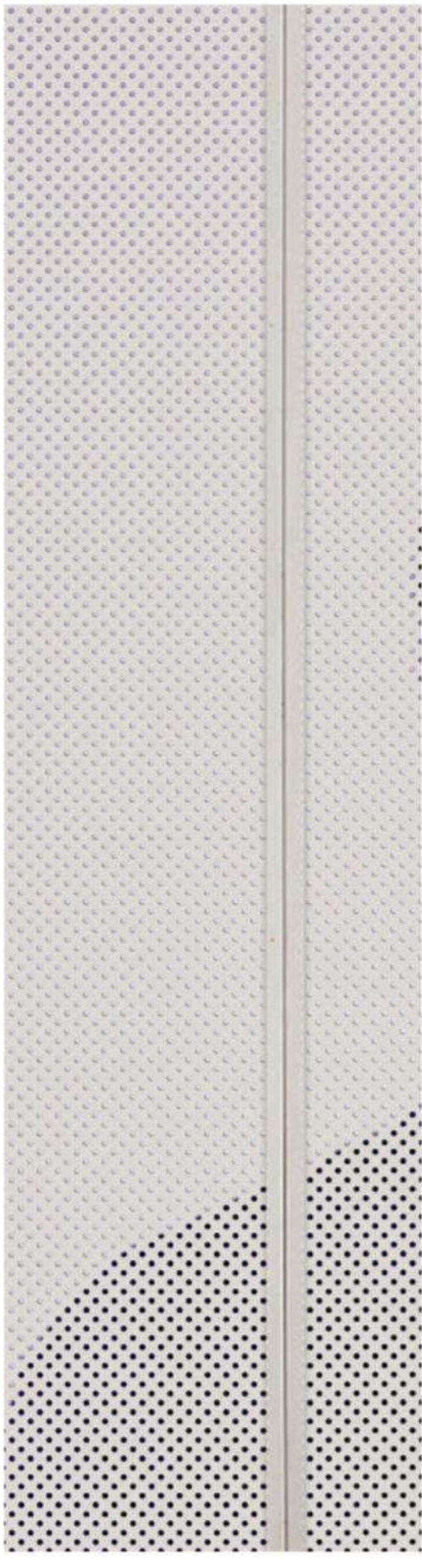
Paranoia, simply defined, is the unfounded belief that others are trying to hurt you. Such unjustified thoughts may include fear of a physical threat or merely the idea that other people are laughing at you behind your back. In some ways, this makes paranoia similar to belief in conspiracy theories (see "The overlap between paranoia and conspiracy theories", page 45). For instance, a believer in such ideas usually suspects that actors are engaged in harmful plots, although for conspiracy theories the target is society at large rather than the individual.

Historically, paranoia has often been talked about as a symptom associated with certain severe psychiatric conditions, says Gregory Scott Brown, founder and director of the Center for Green Psychiatry in Texas. But this is no longer the case. "Almost anyone can end up having these kinds of irrational thoughts, even if they haven't been diagnosed with a mental health condition," says Brown.

In a 2011 study of some 7200 people, for example, Daniel Freeman at the University of Oxford and his colleagues discovered that more than 18 per cent of respondents agreed that there were times over the preceding year when they felt people were against them. The study didn't establish whether the respondents really were being persecuted or experiencing paranoia, but from Freeman's broader research he has been able to establish figures on the prevalence of the condition.

"About 1 per cent of the population have experiences of clinical delusions [that involve paranoia] and are likely to be seen in psychiatric settings, but that is very much the tip of the iceberg," says Freeman. "Somewhere between 1 and 3 per cent of people experience a similar level of severe paranoia although they have never received a diagnosis. And then a further 10 to 15 per cent of people experience milder paranoid thoughts."

Over the past decade, Freeman has begun studying what he calls the paranoia spectrum, defined by the frequency and severity of



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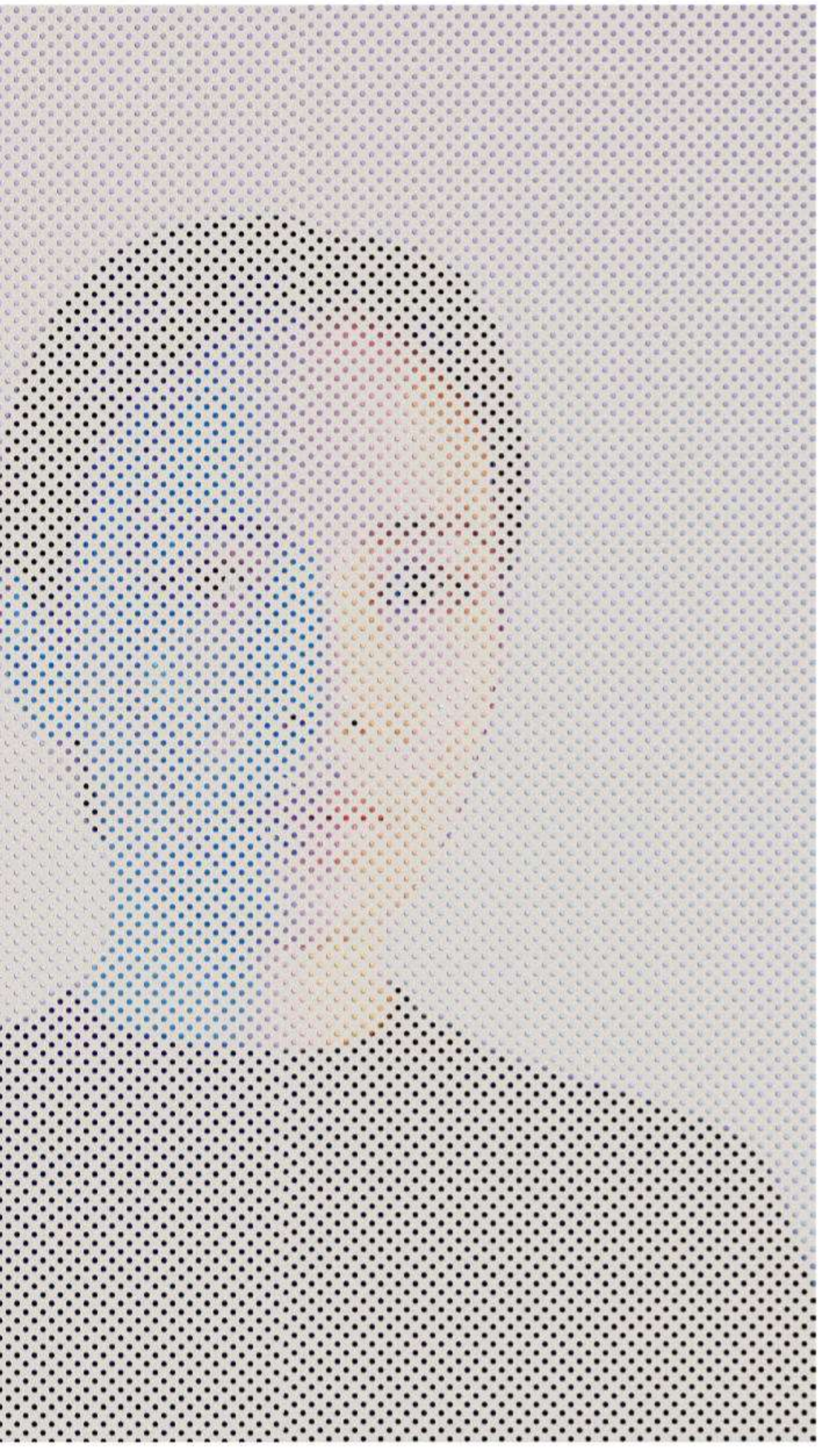


paranoid thoughts. He says that many of us have the potential to develop paranoia depending on what is going on in our lives.

Why are people so susceptible to paranoia? Nichola Raihani at University College London has a surprising answer. She suspects that an innate tendency for mild paranoia might have been beneficial for survival throughout human evolutionary history – and continues to be so even today.

Raihani points out that humans are extraordinarily cooperative. Under the right circumstances, we can benefit from collaborating with people who don't belong to our families or social groups. But cooperating with strangers carries the risk of exploitation, so it pays to be on guard in case collaborators from outside your social group – or what Raihani calls your "coalition" – plan to harm you. "I think of paranoia as being integral to our understanding of what it means to be a social species," she says.

"When the world changes, as it did with the covid-19 pandemic over the past few years, we see that people became more paranoid"

Raihani says existing evidence supports her hypothesis. For instance, one 2016 study examined the link between perceived ethnic discrimination and paranoia in a group of volunteers living in London. The researchers found that the more a volunteer felt discriminated against, as assessed by a questionnaire, the more likely they were to assume that avatars they encountered in a virtual reality simulation intended to upset or distress them. But Raihani and her colleagues have taken the idea further: in a 2018 study, they managed to manipulate volunteers' social expectations in a way that prompted them to have mildly paranoid thoughts.

In their lab-based study, Raihani's team asked US-based volunteers to participate in an online game. In each round of the game, the volunteer watched as a second player – labelled the "dictator" – was presented with $0.50 and given a choice: split the money 50:50 with the volunteer or keep all the money for themselves. After each round, the volunteer was asked to evaluate the dictator's decision. ›

Had they acted in self-interest, just trying to make more money? Or was the dictator motivated by a desire to harm the volunteer's ability to earn?

In reality, there was no way for the volunteer to understand the dictator's motives. However, if Raihani's team revealed that the volunteer and dictator belonged to the same social class or shared the same political beliefs, the volunteer was more likely to assume that the dictator was motivated merely by self-interest. In contrast, if the researchers revealed that the dictator belonged to a higher social class than the volunteer or held different political beliefs, the volunteer was much more likely to believe that the dictator's decision was based on a desire to actively harm them. In other words, the volunteer began to experience paranoia.

Raihani wasn't surprised by this result. "You can think of the general tendency to experience paranoid thoughts as a bit like a volume dial on the radio," she says. "If humans have this ability for a reason, it would need to go up and down based on what you are experiencing. Exposing people to a mild social threat is the kind of thing that turns the dial up for most people."

Understanding uncertainty

Not everyone sees paranoia as a trait we have evolved for its adaptive benefits in social settings. Philip Corlett at Yale University isn't even convinced paranoia is triggered exclusively by social interactions. He says paranoia is better defined as mistrust of the world in general. It is because social connections are such an important and conspicuous part of our lives, says Corlett, that paranoia is typically associated only with a sense of mistrust and suspicion of other people.

One of our brain's most important jobs is to use cues from the environment to predict what will happen next, to help us better navigate an uncertain world, says Corlett. He believes that paranoid thoughts occur when the brain comes up short in its predictive capabilities. This idea implies that paranoia may become more prevalent if life becomes more volatile and unpredictable – which is exactly what Corlett discovered is happening. "When the world changes, as it did with the covid-19 pandemic over the past few years, we see that people became more paranoid," he says.

Corlett could examine this trend because he was involved in researching the causes and prevalence of paranoia before covid-19 began spreading across the world. In work carried out before the pandemic but published in 2020, Corlett and his colleagues asked volunteers in the US to participate in online games, including some that involved no social interaction. In one game, for example, the volunteers were presented with three virtual decks of face-down playing cards. To obtain a high score, they had to use trial and error to work out which deck tended to yield cards with the greatest value. As an added challenge, the volunteers were told that the deck offering the best chance of scoring highly would change at random points during the game.

Corlett and his colleagues also asked each volunteer to complete a standard psychological questionnaire to assess whether or not they were prone to paranoid thoughts. They found that volunteers assessed as being vulnerable to paranoia switched between decks so often that they performed poorly on the game. The researchers think that these volunteers mistrusted the cards, viewing them as far more unpredictable than they really were. This means they couldn't spot the statistical trends that would have helped them identify – and stick with – the high-scoring deck at that time.

Then came the pandemic. Across the world, governments introduced unprecedented policies, particularly lockdowns and face mask mandates. The familiar world became unpredictable. Corlett and his team recruited new volunteers and continued their experiments. They found that the proportion of volunteers assessed via questionnaire as prone to paranoia was significantly higher after the US entered lockdown than before. They also continued to see a correlation between paranoia and poor performance on the card game. This means it is possible that some volunteers began to have paranoid thoughts after the lockdown began, and simultaneously lost some of their ability to respond appropriately to environmental cues.

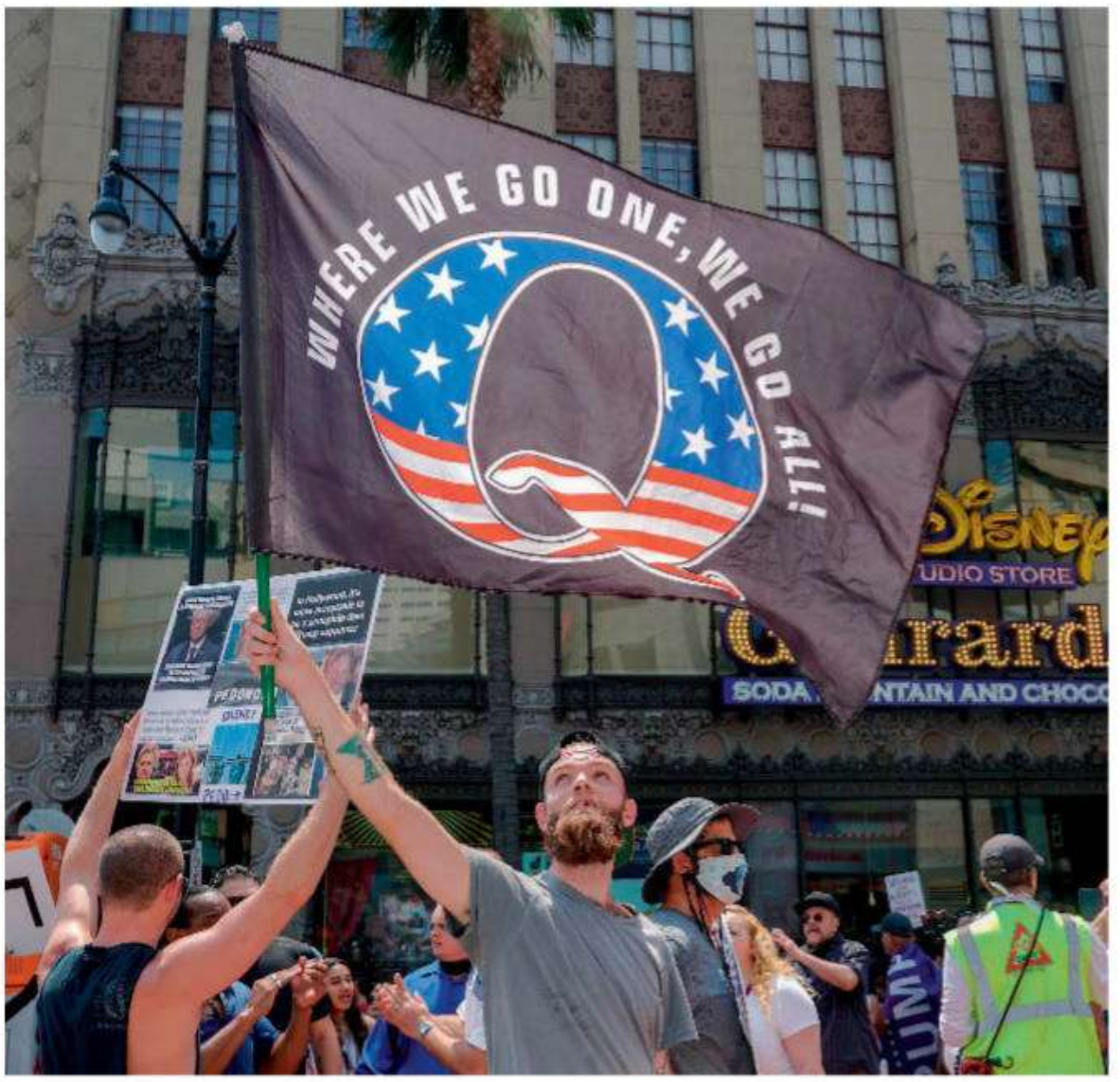
Although Raihani and Corlett have developed distinct explanations for paranoia, they both identify common ground between their hypotheses – particularly the idea that paranoia is at least partly about making predictions from social cues.

Even so, neither hypothesis can yet explain exactly how mild paranoid thoughts relate to the sort of persecutory delusions associated with severe psychiatric conditions. Raihani suggests it may come down to gradually losing sensitivity to social feedback. Corlett says

A place for pronoia?

If our internal cognitive systems can be hijacked to make us think everyone is out to get us, perhaps they could be pushed in the opposite direction. Forty years ago, Fred Goldner at Queens College, City University of New York, suggested that paranoia has a positive counterpart. He termed this pronoia, or the persistent, inaccurate belief that everyone is secretly conspiring to help you. While, theoretically, it is possible that such a condition could exist – and certainly the odd social media post refers to pronoia – there isn't much research to support the idea.

The evolutionary model of paranoia developed by Nichola Raihani at University College London and her colleagues (see main story) may not be compatible with pronoia. "You can think about this in terms of error management theory," says Raihani. Mistrusting someone by mistake – paranoia – may carry a small cost. But the cost of trusting someone by mistake – pronoia – may be far higher. "Evolution favours mechanisms that err on the side of caution," she says.



KYLE GRILLOT/AFP VIA GETTY IMAGES

The QAnon conspiracy theory emerged in the US in 2017

people with more extreme forms of paranoia may experience fundamental issues with the learning mechanisms responsible for updating their beliefs about an ever-changing world.

Nor is it yet completely clear from either hypothesis how to help people struggling with paranoid thoughts. But other research does offer some clues.

Reducing paranoia

Several studies have now demonstrated that excessive worry, sleep disturbances, trauma or low self-esteem all contribute to paranoia. Julia Sheffield at Vanderbilt University, Tennessee, says when you can help people manage these issues, you can reduce paranoia – even in people with severe psychiatric conditions. "It's a very simple strategy," she says. "But when you can reduce those worrisome thoughts in people, taking that time to build meaningful activities into their lives instead, they don't need the paranoia."

Freeman's research supports this point. His team has found it is possible to reduce paranoia in people with persecutory delusions by asking them to schedule "worry periods" during which they are permitted to worry. Outside of those periods, if they felt prone to intrusive thoughts, they were asked to instead engage in healthy activities, like going for a walk or spending time with loved ones.

It is even possible to use online tools to help some – although not all – people with these intrusive thoughts. In a 2017 study, Freeman and his colleagues found that online cognitive behavioural therapy that improves sleep can also help reduce feelings of paranoia.

"When people are struggling with paranoia, they are spending too much time going over the suspicious and paranoid thoughts – and they get reinforced. That's what pushes us along the spectrum," says Freeman. This is why techniques to limit those thoughts are helpful.

"If you are feeling more depressed, you are having problems sleeping or your self-esteem is going down, that is going to increase your vulnerability to paranoia," says Freeman. "The route to treating the paranoia is helping people manage these other mechanisms – that is what is going to help the most." ▮

Kayt Sukel is a science journalist based in Texas

The overlap between paranoia and conspiracy theories

QAnon supporters believe a group of Satanic, cannibalistic paedophiles plotted against Donald Trump during his time as US president. Why do some people find such conspiracy theories so alluring? The study of paranoia may provide some clues.

In a recent study, Philip Corlett and Praveen Suthaharan at Yale University found a 60 to 70 per cent correlation between people who have paranoid thoughts and those who believe at least one conspiracy theory. The pair then investigated the individuals' social networks to better understand how conspiracy theories might proliferate in people with mild or more severe levels of paranoia.

"We expected that more paranoid people who believed these theories would be lonelier and more isolated," he says. "The result we got was the opposite: they believe other people share their beliefs." Supporting a conspiracy theory was a positive thing for them, he says.

So, given this benefit, is it possible to steer a friend or loved one away from an easily debunked theory? It's not easy, says Corlett. He advises against directly challenging the individual, but instead suggests asking them to come up with potential alternative explanations for their theory. "Forcing your explanation on them is likely to backfire on you," he says. "So meet people on their level, without ridiculing them, and try to find some common ground. That's always a good place to start."

In the shadows

With each passing decade, dark matter hunters have had to get ever more creative. Will they ever give up, asks **Michael Brooks**

IF YOU happen to pass through Antarctica later this year, you could be greeted with a peculiar sight. Peel your eyes away from the penguins and you might spot something unusual floating in the sky: a balloon the size of a stadium. Trailing below it will be the latest mad-sounding experiment designed to look for the most maddening thing scientists have ever dreamed up – dark matter.

We reckon around 85 per cent of the universe's matter is exotic stuff that doesn't reflect, emit or absorb light, which is why it is called dark matter. The only force that this hypothetical stuff definitely deigns to interact with is gravity, as far as we know, which makes it incredibly difficult to detect. "When I gave talks on this in the 80s, I was telling people, 'Oh, we're going to figure this out in 10 years'," says Katherine Freese, an astrophysicist at the University of Texas at Austin. Decades later, we are still waiting. "It's obviously a harder problem than we realised."

In the face of that hard truth, dark matter hunters have become ever more inventive. Attempts over the years to pin down what it is made of include burying vats of liquid xenon deep underground, measuring the straightness of lightning bolts, a plan to detect nanoscale explosions in minerals, examining ancient rocks for dark matter scars and checking the James Webb Space Telescope's observations for "dark stars". All of which raises the question: are some suggestions for dark matter searches a long shot too far? And at what point would we consider giving up the chase?

The first hints that something dark permeated the universe came in the 1930s, when astronomers spotted something odd. Clusters of galaxies were rotating far faster than they should have been, for instance. At such rotation speeds, from our understanding of gravity and dynamics, some of their constituent parts should have been flung off into the depths of space, but they were holding together. Maybe, suggested Swiss astronomer Fritz Zwicky, there was some matter that we couldn't see holding everything in place.

Galaxy glue

The hunt for Zwicky's "dark material" never really took off, partly because there were lots of questionable assumptions behind his assertion. Things changed in 1970, though, when Vera Rubin and Kent Ford at the Carnegie Institution of Science in Washington DC made a surprising discovery about the Andromeda galaxy. They noticed a small-scale version of Zwicky's observation: the stars within the galaxy were rotating around its centre faster than expected. They should have been flung off, but, again, something was holding them in place.

This is when the hunt for dark matter began. Rubin predicted we would know exactly what this strange galaxy glue was within a decade. 1980 came and went, however, and we were none the wiser. In 1999, English Astronomer Royal Martin Rees again predicted we would have found it within a decade. We didn't. "My confidence in us quickly pinning down the nature of dark matter was certainly misplaced," says Rees. Today, we still don't know what dark matter is made of.

The decades since Rees's prediction have helped us rule out a few potential candidates. Peering into the distant universe has led us to be pretty sure that it isn't comprised of massive planets or black holes, known as massive compact halo objects, or MACHOs. If it were, we would probably have seen these objects bending cosmic light in predictable ways.

For much of the past 40 years, physicists have been on the search for another dark matter candidate: weakly interacting massive particles (WIMPs). These would be particles not found in the standard model of particle physics, our current best understanding of the forces and particles that make up the most fundamental building blocks of nature.

WIMPs were dreamed up with all the attributes dark matter seemed to exhibit. They also had the desirable virtue of being within reach of purpose-built detectors, should their trajectory happen to collide with an atomic nucleus. If a WIMP gave it a reasonable kick, the nucleus's recoil energy would then be released as a flash of light that we could spot.

Getting a detection requires having a lot of large nuclei. That led physicists to design and build detectors that use enormous vats of supercooled liquid xenon, ready and waiting for a kick from a WIMP. These kinds of experiments are still widely considered our best bet to find ›

MICHAEL KIRKHAM

Dead ends?

Some dark matter searches are ongoing, but others seem to have culminated in failure. Here are a few examples.

Seasonal flashes
Scientists working on an Italian experiment called DAMA/LIBRA claim to have observed a seasonal signal: flashes from their crystals that are more frequent in June than in December. This, they say, could be the result of dark matter interactions changing in intensity as Earth circles the sun. But, say other physicists, there are good reasons to doubt that claim. For starters, the researchers involved haven't released their raw data for independent scrutiny. And then there is the issue that another group recently showed, that an error in the analysis could have given exactly the seasonal signal seen.

Nano-bombs
An alternative to vats of liquid xenon for detecting dark matter particles (see main story) are nano-bombs that could be detonated by dark matter. In 2014, Alejandro Lopez-Suarez at the University of Michigan and colleagues pointed out that a nanometre-scale sliver of metal will heat up if struck by hypothetical particles of dark matter called WIMPs. Embed the metal in an oxide mineral and the heat will trigger a thermite reaction — a tiny, but detectable explosion. Tests of the idea never got funded.

Straight lightning
Nathaniel Starkman at the University of Toronto in Canada and his colleagues think dark matter might reveal itself in lightning. This idea envisages dark matter as unusual agglomerations of "normal" particles, such as the quarks and gluons that make up atomic nuclei, that could have stuck together in the early universe in small, dense lumps and that might be speeding through the cosmos today. If they hit our atmosphere, they would ionise any molecules they collided with. If that happened during a storm, we might see a poker-straight bolt of lightning, rather than the usual jagged ones. When the idea was first proposed in 2021, no one had seen straight lightning. Then, in February 2022, the team excitedly posted a preliminary paper online about a potential sighting. Sadly, it wasn't what it first seemed and the paper was removed.

dark matter. The latest is the DARWIN detector proposed for the Gran Sasso Laboratory in Italy, which will use 50 tonnes of xenon. Annual global production is around 70 tonnes; physicists really are going all out on this idea.

But there are no guarantees. For a start, most of the potential masses that WIMPs might come with have been ruled out. If WIMPs were on the heavy side, we would have seen them by now in underground vats or as a product of protons smashing together at the Large Hadron Collider near Geneva, Switzerland.

The tricky thing with WIMPs is that the lighter they are, the harder they are to find. Most current detection methods largely rely on the WIMP having a certain minimum mass, around that of 10 electrons. "[Detectors] are underground waiting for a dark matter particle to hit a xenon atom and make it wiggle," says Martin Bauer at Durham University, UK. "But if the particle is too light, the xenon atom is not going to recoil." In that case, physicists run into another problem. Neutrinos produced by the sun are passing through Earth in their trillions every second. They would also leave traces in the xenon that are impossible to disentangle from those of light WIMPs. "There's no way to shield against solar neutrinos," says Bauer.

One alternative looks deep into the past. This is arguably the most impactful melding of archaeology with astronomy since we first made sense of Stonehenge. The idea is simple. WIMPs might, just occasionally, have knocked an atomic nucleus out of place in a crystal of rock salt or epsomite deep in Earth's mantle. If this happened, relatively new technologies such as X-ray or helium-ion beam microscopy might be able to see these displacements as tiny, telltale tracks in ancient rocks.

This particular hunt for dark matter is starting to come together. "We've got geophysicists telling us which rocks to look for," says Freese. "We did the calculations to figure out how much rock you would need to see a definitive trace from dark matter, and it's not that much." Once the rocks are extracted, the researchers performing the dark matter palaeo-detection will have to act fast, because cosmic rays will then start to leave similar nanoscale tracks in their structure. But it should still be possible to distinguish these from those caused by WIMPs and those created by fission products released by naturally occurring uranium.

Freese, for one, is loving the hunt for dark matter, which she has been involved with for decades now, calculating how various kinds of particles might be discovered. "It's rough that nothing's been seen, but the calculations we did were just the easiest ones to find," she says. "I'm not giving up. In fact, we're really having fun."

Some researchers get their kicks by chasing alternative hypothetical particles, such as the axion. Unlike WIMPs, axions weren't cooked up as part of the search for dark matter. Instead, they were first proposed as an attempt to solve an anomaly where experimental data and an aspect of quantum theory don't quite match up. But axions should also have the properties we associate with dark matter. And, in experimental terms, the search for them is pretty much a blank slate. The only experiment running right now seeks to convert axions to microwave photons using a strong magnetic field, but other approaches, such as looking at the light from the sun or seeing axions' effects on magnetometers, are being developed.

Still others are looking for a dark equivalent for each particle in the standard model. Searches for this "dark sector" have begun, with researchers firing high-intensity electron beams at targets in the hope that they might emit a "dark photon", for instance. That would

XENON1T looks for signs of WIMPs in vats of xenon

CORRIERI–DE PERIO/LNGS–INFN

“It’s rough that nothing’s been seen, but I’m not giving up. We’re having fun”

be massless, so it wouldn’t be dark matter exactly, but it would tell us the dark sector is real – and compel us to hunt other dark particles. “A lot of people are working on the dark sector,” says Freese. “Lots of things like dark photons are not that much of a stretch.”

But particles aren’t the only contenders. Freese is also looking for “dark stars” – balls of dark matter that could have formed in the early universe. One hypothesis says that if dark matter particles interact, they annihilate. If dark matter interacted with itself just a little bit, this would release enough energy to create stars long before the ones we are familiar with started to shine. As Freese and her colleagues reported last year, instruments on the James Webb Space Telescope (JWST) might be able to show us these stars. Due to their distance from us in an expanding universe, their light would appear redder than less ancient stars. “[JWST is] already finding too many bright objects at high redshift. Once we get their spectra, we should be able to learn something about them,” she says. “We’ll be asking as the data comes in, could this be a dark star?”

Clearly, the possibilities are legion. For some, though, the fact that pretty much “anything goes” is a sign that the whole enterprise is a wild-goose chase (see “Dead ends?”, left). “You can’t just keep moving the goalposts,” says Stacy McGaugh at Case Western Reserve University in Ohio. “There has to be a point at which you decide you’ve done what you can, and you stop.” McGaugh gave up on dark matter decades ago. Now, he is working on the idea that we can explain the galaxy rotation anomalies in a different way.

Redefining gravity

McGaugh is a supporter of what is called modified Newtonian dynamics (MOND) – a controversial idea that proposes rewriting the laws of gravity. One way to do this is by altering the equation of Newton’s law of universal gravitation in a way that changes how strong gravitational attraction between two masses is over cosmological scales. McGaugh claims that, in many cases, it provides a better fit to observational data than dark matter. Most importantly, he says, it has a predictive power. “You can look at a galaxy, observe its distribution of mass and you can use MOND to predict the way everything moves,” says McGaugh. “You can’t do that with dark matter.”

Most astrophysicists dismiss the idea. “They’ve never demonstrated that they can explain all the basic observations that we have,” says Kathryn Zurek at the California Institute of Technology. It falls short, she says, in explaining the features of the radiation left over from the big bang, known as the cosmic microwave background. “You just can’t get all of that from MOND.”

McGaugh admits that MOND doesn’t make sense of all our observations, but, he says, it has scored some successes over dark matter. For one, JWST spotted old galaxies that are brighter than they should be according to standard cosmological theory. In 1998, McGaugh points out, Robert Sanders at the University of Groningen in the Netherlands found that modified gravity would result in bright galaxies forming extremely early in the universe’s history – by 500 million years after the big bang. “That’s exactly what we’re seeing now,” says McGaugh.

Most in the field are a long way from being ready to give up on dark matter, though. We may have ruled out a few potentials, says Rees, but plenty remain. “The odds in favour of some as-yet-unspecified particles constituting the dark matter are not significantly reduced.”

Perhaps the Antarctic blimp will find antiprotons – the antimatter equivalent of protons – in the flux of cosmic rays that stream towards Earth from space. Models of dark sector dark matter predict the existence of low-energy antiprotons in this particle stream, so any detections during the planned series of 35-day flights would be an exciting development.

Even if nothing turns up, it is important to note that the search for dark matter is a relatively small-scale enterprise. We spend far less on it than we do on high-energy physics or quantum computing research, says Zurek. “Plus, we’re learning stuff,” she says. “It’s taught people to not be quite so dogmatic about how nature should behave. It’s useful and humbling.”

No one can know when, or how, or even if, dark matter will show up in the end. But Zurek is OK with that. “I think we’re going to have to get lucky,” she says. “But if we don’t look, we’re certainly not going to find it.” ▮

Michael Brooks is a freelance writer and consultant for *New Scientist*

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Science of gardening

Stag party

Make your garden more enticing for wildlife with a few log piles, says **Clare Wilson**, and you may glimpse some stunning beetles

Clare Wilson is a reporter at *New Scientist* and writes about everything life-science related. Her favourite place is her gardening allotment @ClareWilsonMed

What you need

Logs, responsibly sourced
A spade

Science of gardening appears every four weeks. Share your gardening successes with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistGardening

Next week

Citizen science

ONE of my garden jobs at the moment is pruning any trees and woody shrubs at a time of year when there are no leaves in the way. Instead of throwing away the branches, I will be creating a few small log piles to help make my plot a more tempting site for the local wildlife.

As dead wood rots, it becomes a food source or home to thousands of species, including mosses, lichens, fungi, beetles, flies, hoverflies, spiders, moths, wasps and bees. In turn, these will be food for larger animals like birds, lizards, frogs, toads and small mammals such as hedgehogs.

If your own garden lacks any trees that need pruning, don't be tempted to collect branches from the wild, as the animals living there need them too. Instead, you could source free logs through online sites like Freecycle or by contacting local tree surgeons. Aim for a variety of log sizes, but it is good to get some thicker ones in the mix.

Once you have your wood, the question is where to put it. In full sun, the log pile will quickly dry out and support less life. In deep shade, the wood will become cold and wet – good for fungi, but not so much for insects. Ideally aim for sites in dappled shade or that are shaded for part of the day.

Another way to make a mix of habitats is to bury some of the wood, for instance by standing a few of the logs upright, up to half a metre deep if possible. This will help the wood rot faster and will be appreciated by those creatures living underground. If you have had a tree cut down, then leaving the stump in place would do the same job.

ROSS BOWER

In my part of the world, underground rotting wood should attract stag beetles, which are a threatened species. They are found in parts of central and southern Europe, including southern England and Wales. They have even occasionally been sighted as far north as the Lake District, according to Laura Bower at the People's Trust for Endangered Species, a UK charity that is asking people to make log pile homes for the beetles.

Reaching up to 8 centimetres long, with the males having oversized antler-like jaws, stag beetles are the UK's biggest beetle. They spend several years as larvae, which live underground and eat rotting wood. These grubs can reach an alarming 11cm in length. In May to July, they emerge as adults, ready to mate. The males don't even use their iconic jaws for eating – just fighting.

Thanks to my new log piles, I might be seeing some stag beetles in action in my own garden in a few years, as the females usually stay close to where they emerge from the ground. So while I might currently be shivering in the depths of a UK winter, I am dreaming of warm summer evenings spotting stag beetles taking flight and slowly whirring around my garden.

These articles are posted each week at newscientist.com/maker

Swansea University
Prifysgol Abertawe

Computational Foundry
Ffowndri **Gyfrifiadol**

EPSRC Centre for Doctoral Training in Enhancing Human Interactions and Collaborations with Data and Intelligence Driven Systems – Call for Applications for 4-year Funded research studentships.

"Permacrisis" is the Collin's Dictionary word of 2022, reflecting the very real global concerns we have all experienced. It is easy to despair but at Swansea University we are working to use AI and data-driven systems to bring hope and transformation. We do this by focussing on the most important technology of all: people. We are now looking for the next group of PhD researchers to join our Centre, people who are committed to changing the world via world-class research that focuses on amplifying human capabilities using data driven and intelligence enabled systems. The programme spans 4-years and includes an integrated Masters.

Working alongside a rich and diverse set of partners – including Facebook, Siemens, Tata, NHS and Google – successful candidates will use a people-first approach to drive exciting, adventurous and impactful socio-technical breakthroughs.

The Centre is housed in the state-of-the art Computational Foundry at Swansea University. Members of the Centre will be nurtured by multi-disciplinary supervisors with globally leading research agendas in Computer Science, Mathematics, Engineering, Management, Medicine and Social Care and Law. If successful, you'll be part of a community of 40+ PhD researchers, each supporting and learning from each other.

Candidates should have an aptitude and ability in computational thinking and methods including the ability to write software or enthusiasm to learn how to do so. While such aptitude might be evidenced by a degree in Computer Science or Engineering, we are building a community that aspires to have a high degree of diversity of perspective. So, if you have a background in Arts and Humanities; Social Sciences; Management for instance, please be encouraged to apply.

For future AI and big data technologies to serve society and the economy effectively, they must be created and critiqued by a diverse and wide set of perspectives as possible: we welcome applications from anyone who feels they can help in the Centre's mission.

This year, we have 12 fully funded places (fees plus stipend set at the UKRI rate). Places are also available for those in receipt of four-year external funding. We welcome candidates from anywhere in the world.

To discuss your application, please contact Professor Matt Jones (Director-Enhance-CDT@swansea.ac.uk)

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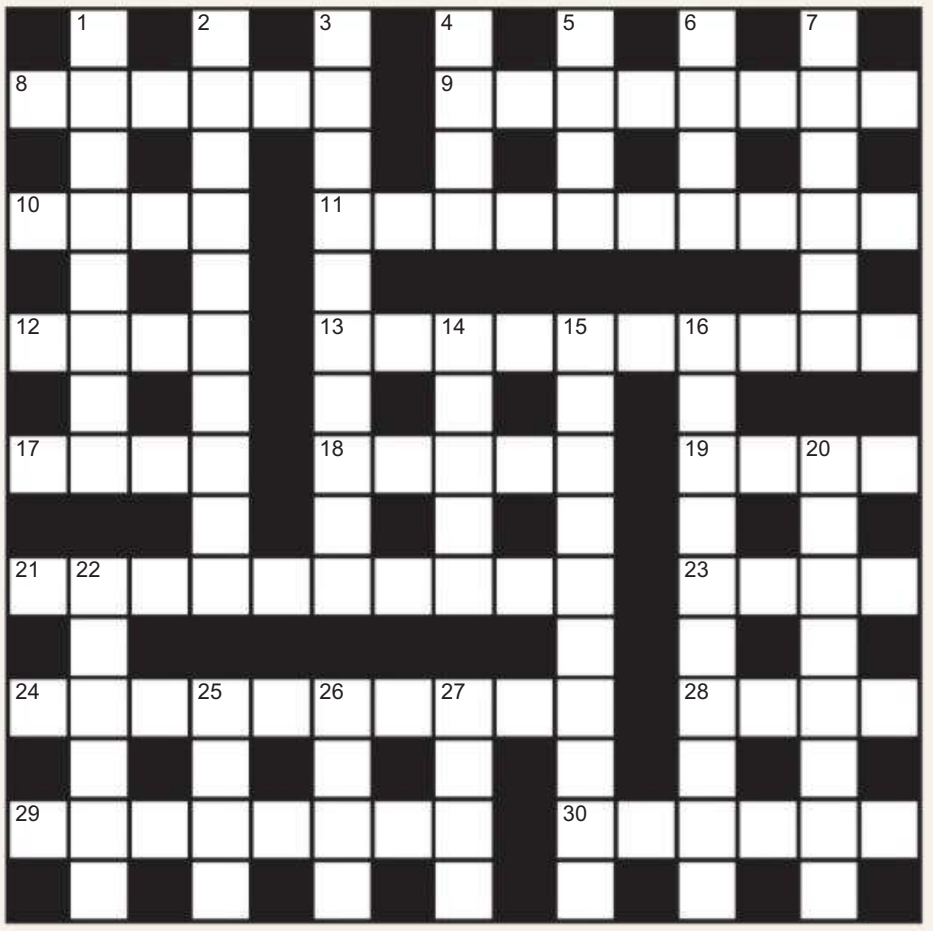
Quick crossword #126 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

8 John ___, physicist, chemist and colour-blindness researcher (6)
9 Tropical tree of South-East Asia (8)
10 Videoconferencing software launched in 2011 (4)
11 Tropical tree of South-East Asia (5-5)
12 Zn (4)
13 Not working properly (informal) (2,3,5)
17 Abominable snowman (4)
18 Active substance; autonomous entity (5)
19 US space exploration agency (4)
21 Student; academic (10)
23 Give out (4)
24 Device for precise measurement of small components (10)
28 Information (4)
29 Tropical hardwood (8)
30 Nintendo games console (6)

DOWN

1 Engineered hardboard (8)
2 Basic nuclear reactor (6,4)
3 Armoured dinosaur of the Late Cretaceous (10)
4 Killer whale (4)
5 Type of intense air pollution (4)
6 Body of a ship (4)
7 Astringent polyphenol (6)
14 Molars and incisors, for example (5)
15 Starship captained by James T. Kirk (10)
16 Lubricant derived from flax (7,3)
20 Pain in the leg and lower back (8)
22 Thomas ___, inventor (6)
25 Anchoring plant organ (4)
26 Natural satellite (4)
27 System of units of mass, used particularly for precious metals (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #188
set by Bethan Ackerley

1 Thunderstorms are associated with what kind of cloud?

2 The Thule were the ancestors of which modern Indigenous culture?

3 What does the "m" in mRNA stand for?

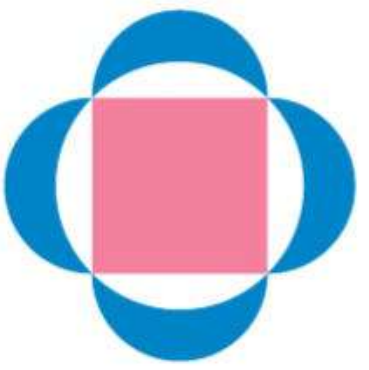
4 Chytridiomycosis is a disease that affects which class of animals?

5 Wormholes are known by another name that honours two scientists, Albert Einstein and who else?

Answers on page 55

Puzzle
set by Howard Williams
#208 Flower power

Ivor Plant is the head gardener of Lady Bird's estate. Her large chrysanthemum garden needs to be weeded and pruned, so he assigns his two apprentices, Lupin and Heath, to the rather tedious task. The garden consists of a central 4-metre-sided square (pink) inscribed in a circle, and four outer areas (blue) enclosed in semicircles that are connected to the square's corners.



"If you give me two of your chocolate biscuits, I will let you pick whichever area you want to weed: the outside or the inside," says Heath to Lupin. Always eager to get out of extra work whenever possible, Lupin agrees. If he is looking to weed the smaller of the two areas, should he choose the blue or the pink section?

Solution next week

All aboard

What is the most efficient way to load passengers into an aircraft: randomly; in blocks; or the passengers in window seats first, followed by those in middle seats, then those in aisle seats?

David Roffey
London, UK
The answer is complicated. It depends on what you mean by efficiency, as well as on some pretty important assumptions.

If you just look at the time taken to seat everyone – assuming the passengers are all single people who can follow instructions, briskly walk to their assigned seat, put a single bag into the overhead locker and sit down – there would be surprisingly little difference between the answers. But studies have suggested that the winning strategy in this case is to fill the window seats (from the rear to the front), then the centre seats and, lastly, the aisle seats.

Now, the caveats. Firstly, to measure the total efficiency of the operation, you also need to count the time it takes to get everyone to the door in the right order. The more factors in the desired ordering, the longer it will take. This would almost certainly eat into the difference between the method described above and a simple rear-to-front ordering.

"The semi-random order that airlines habitually use to board passengers onto planes is the least worst overall"

Also, people come in groups and don't want to be separated. They often don't have just a single, small bag that fits neatly into the overhead locker, either, and so leave less room for the remaining passengers' bags. This means progress is likely to be disrupted by people looking for bag space and blocking the aisle.

Lastly, people don't actually board in the order they are called to do so. Stopping passengers to check whether they are following the rules takes more time than it saves, reducing efficiency.

So, not too amazingly, the semi-random order in which airlines habitually carry out this operation is the least worst option overall – particularly in reducing the emotional energy that has to be expended by the crew.

Chris Daniel
Glan Conwy, Conwy, UK
In 2014, the *MythBusters* television series tested six different boarding methods using a mock-up of an aircraft cabin and 173 volunteers acting as passengers. They found that filling the seats in window-middle-aisle order (the "WILMA" method) and variations of this technique were the most popular and almost the fastest, taking around 15 minutes.

Random boarding with allocated seats was about two minutes slower. Random boarding with no allocated seats was the fastest method tested, taking about 14 minutes, although both of these methods were chaotic and the least popular.

The block boarding method, which is the one most commonly used by airlines, was the slowest, taking on average 60 per cent longer than the others. The delays are largely caused by the queue of passengers in the aisle being brought to a halt by people at the front stopping to load their luggage into the overhead lockers.

Other methods have also been tried by airlines. One, devised by astrophysicist Jason Steffen in 2008, is nearly twice as fast as block boarding. It is similar to WILMA, but passengers board in alternating rows, on one side of the plane at a time, from back to front. This improves the likelihood that passengers will reach their seats unimpeded. It is, however, difficult to implement routinely.

The "Flying Carpet" method is claimed to be the quickest of all. Passengers assemble in groups of 30 or 40 in the corridor leading to the plane, where the floor is marked with a grid corresponding to their seat numbers. Passengers then board in this exact order.

There are several reasons for airlines continuing to use inefficient boarding methods. One is that the frustrations due to the delays they cause can be turned into a revenue stream in the form of priority boarding passes.

Philip Morey
Kalaru, New South Wales, Australia
Pre-seat passengers outside the plane, then forklift blocks of seats into it from a rear opening, such as the type used in the military plane the C-17 Globemaster III.

David Cunnold
Bath, UK
Usually, we sit in the departure lounge until the queue has boarded. We then take a gentle stroll to the gate and on to our two aisle seats on the aeroplane. Job done, never missed a flight yet.

BILLION PHOTOS/SHUTTERSTOCK

Should a toilet roll face outwards or inwards? Which side are you on?

This week's new questions

Rolling dilemma **Which is the best way to put a roll of toilet paper onto the holder: rolling towards you or away?**
John and Margie Cleveland*, Bloomington, Indiana, US*

Wonky weather **How would global weather patterns change if Earth were to rotate in the opposite direction?**
Euring John Bibby*, Malvern, Worcestershire, UK*

Divided loyalty

Why is it that less than 5 per cent of mammal species are monogamous, compared with about 90 per cent of bird species?

Hazel Russman
London, UK
This is a consequence of what is known as Trivers's cruel bind, named after the evolutionary biologist Robert Trivers.

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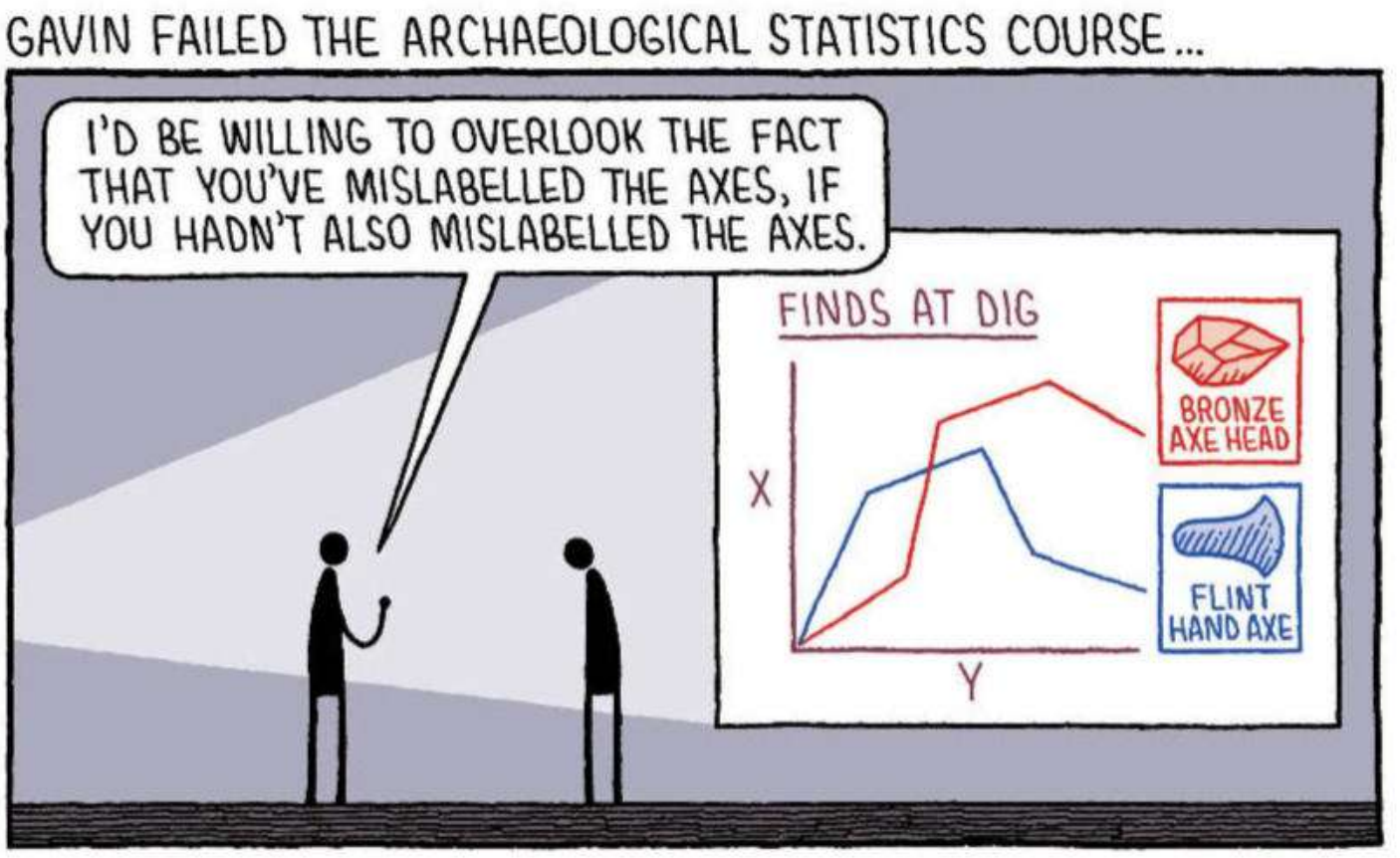
Tom Gauld
for New Scientist



A male animal that impregnates a female leaves her literally holding the baby. She then has to raise any infants to the best of her ability because they might represent her entire genetic investment for the year. The male is free to go off and impregnate other females, increasing his contribution to the next generation. But this will only work if the female is, in fact, capable of raising young on her own.

Most female mammals can do this because they produce milk to feed their young. Occasionally, this isn't enough. Wolves, for instance, are endurance hunters, and a lactating female can't follow prey for hours on end. So, she needs a faithful mate to bring food to her while she is raising her cubs.

Among birds, only pigeons and a few other species produce any kind of milk. Chickens and game birds have young that can feed themselves almost immediately, so males can safely leave them in Trivers's cruel bind. But most birds produce young that are naked, blind and helpless. They need to be brooded, kept warm and fed a high-protein diet, such as insects (songbirds) or meat (raptors). This takes two partners.

"Most male birds are monogamous because it is the only way they can be sure of having any surviving offspring"

Most male birds are monogamous because it is the only way they can be sure of having any surviving offspring.

David Muir
Edinburgh, UK

Evolution has equipped animals that reproduce sexually to do so in the most efficient manner to pass on genes to their progeny. Most female mammals can successfully raise at least some of their young by themselves, so males go off to spread their genes elsewhere.

Birds need to leave the nest to find food, leaving defenceless eggs or hatchlings behind. For a male to maximise his genetic success, it is best for him to stay with the one female, share parenting and help protect his genetic investment. However, some birds vary their reproductive strategy.

Hedge sparrows, also known as dunnocks (*Prunella modularis*), adapt to different mating modes depending on the availability of food. Less food means territory size has to be larger and more likely to overlap with neighbours' territories, leading to greater opportunity to interact with more dunnocks. This socialisation leads to cooperation in defence of territory and much more besides.

Four reproductive strategies are recorded in *P. modularis*: monogamy; polyandry, between one female and more than one male; polygyny, between one male and more than one female; and polygynandry, a reproductive relationship between more than one male and more than one female. DNA fingerprinting has demonstrated that chicks in the same brood often have different fathers, and it isn't that unusual to see multiple parenting at the same nest. ▮

Answers

Quick quiz #188 *Answers*

1 Cumulonimbus
2 The Inuit peoples
3 Messenger
4 Amphibia
5 Nathan Rosen (wormholes are also known as Einstein-Rosen bridges)

Cryptic crossword #102 *Answers*

ACROSS 7 Reveal, **8** Cougar, **9** Flak, **10** Mammoths, **11** Harrier, **13** Egest, **15** Spica, **17** Chinook, **20** Knapping, **21** Topi, **23** Viking, **24** Isopod

DOWN 1 Bell, **2** Beaker, **3** Clamber, **4** Scamp, **5** Dugong, **6** Machismo, **12** Appendix, **14** Chagrin, **16** Capsid, **18** Notion, **19** Rings, **22** Prow

#207 Total recall *Solution*

The extraterrestrial beings are aged 3, 10, 11 and 40.

Call the four ages a, b, c and d. Each age has been added three times, so 24 + 53 + 54 + 61 is equal to 3(a + b + c + d), hence the ages add up to 64 all together.

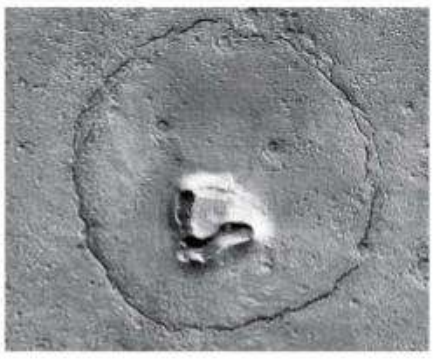
We know that the smallest three add up to 24 and the largest three to 61, so the largest number must be 37 more than the smallest.

We can also see that, since the middle two combinations are 53 and 54, the middle two ages must differ by 1.

From here, the solution can be found quickly.

Mars bears

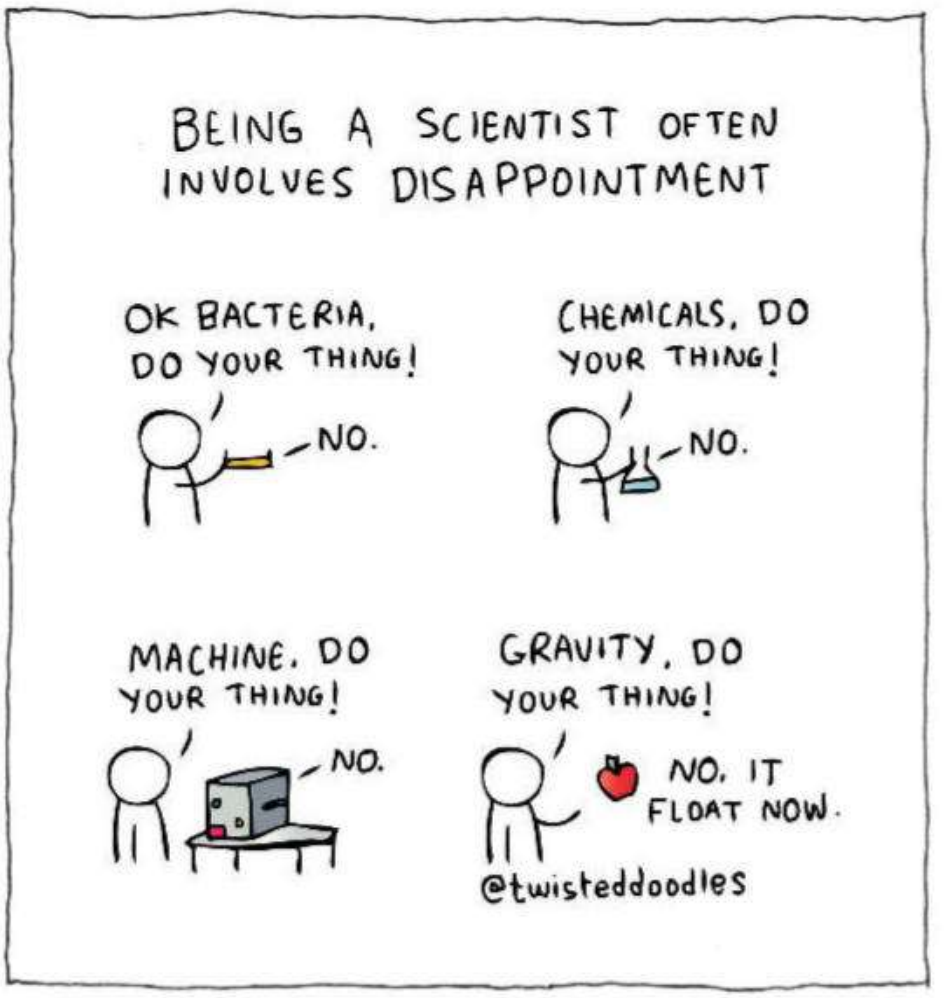
A smiley-faced bear, discernible in a NASA satellite's image of the surface of Mars (below), is inspiring smiles on the faces of humans on the surface of Earth.



Similar discoveries have garnered two Ig Nobel prizes. Richard Hoagland was awarded the 1997 Ig Nobel prize for astronomy for his work, in which he claimed to have identified giant artificial structures in NASA photos, including a human face on Mars. Later, others realised that the face was just made up of shadows cast by hills. The reinterpretation was efficiently summarised in a *New Scientist* headline: "Martian conspiracy theorists lose face".

This kind of mistaken interpretation is called pareidolia, and Kang Lee and his colleagues received the 2014 Ig Nobel prize for neuroscience for studying it. They were trying to understand what happens in the brains of people who, for example, can see the face of Jesus on a piece of toast.

Twisteddoodles *for New Scientist*



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Focus on cannabis

Can cannabis make people more efficient at doing repetitive work? With a few exceptions, research about cannabis seems to have had difficulty focusing on the question. Researchers have mostly looked in the opposite direction, asking how much does cannabis impair a person's work, cogitation or professional prospects.

A study in *Performance Enhancement and Health* brings some cheery info, though not much data. Niki Kiepek and her colleagues at Dalhousie University, Canada, surveyed 370 women and 145 men. They explain that "Cannabis was used to enhance motivation to engage in household activities", that "Men were more likely to report cannabis reduced boredom" and that some women "had switched to oral consumption of cannabis gummies to reduce judgments associated with smoking".

A Nigerian study from 2015 hints at a cannabis boost to efficiency. Manasseh Iroegbu at the University of Uyo, Nigeria, is lead author of "Exploring the performance of mason workers in the construction industry: New evidence from the use of cannabis at work site in a field experiment".

Forty masons were "given each a wrap of cannabis". Another 40 were not. The study says: "A delay time of 30 minutes was allowed after smoking for the cannabis effect to peak. Thereafter, the 80 masons started work at the same time which involved the laying of blocks." During the next 4 hours, the smokers "performed higher than the nonsmokers".

Alas, that is almost all the detail we are given. The subsequent years have brought mystery. The study is no longer online, nor is the journal – *Social Sciences and Psychology* – where it appeared.

Real-life romance noir

Romance can be challenging, especially when one of the romancers seems "dangerous" or "gross", or has a personality bursting with "Narcissism, Machiavellianism, and psychopathy", three qualities known as the dark triad.

The conjunction of seamy personalities and romance is much studied by psychologists, perhaps none more diligent than Peter Jonason, who has published about 200 studies on the dark triad. His latest, "Six 'red flags' in relationships: From being dangerous to gross and being apathetic to unmotivated", appears in *Personality and Individual Differences*. It explains that, for women and some men: "The most repelling factors in the long-term context were being apathetic and gross, and in the short-term context they were being gross and clingy."

Jonason has another study coming out in the same journal. The title is: "The Napoleon complex, revisited: Those high on the dark triad traits are dissatisfied with their height and are short". It is classified as a "Short Communication".

A little bit missing

While astrophysicists try to identify the "missing mass" that constitutes most of the universe, authorities in Western Australia had to search for a specific, tiny chunk of mass that went missing.

The government quietly blared an alert: "Emergency services are searching for a capsule containing a radioactive substance and are asking the public to be alert and report anything that looks like the missing material." The capsule is tiny (6 millimetres in diameter, 8 millimetres tall). Its content – "a small quantity of radioactive Caesium-137" – is, of course, even tinier. That was the bulk of the info given to the public. After a few days, roadside searchers found it.

That capsule temporarily joined its older conceptual siblings in the public historical record. Most of those are US nuclear bomb cores, six of which went missing between 1950 and 1968. There may be others, their missingness recalling Tom Lehrer's ever-pertinent lyric in his song about Nazi and then US rocket designer Wernher von Braun: "Once the rockets are up, who cares where they come down? That's not my department, says Wernher von Braun!" ▮

Marc Abrahams

MANCHESTER 1824
The University of Manchester

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ON OUR WATCH

Hope can now be spotted across all our planet's seas and oceans. Sites are made into aquatic havens by local communities, to safeguard the richness and diversity of the ecosystems they depend on. Sylvia Earle's invaluable experience as an explorer and marine biologist continues to help further their goal, through her organisation, Mission Blue. Together, they have created over 130 Hope Spots and counting. Carrying a message of hope for generations to come. It is that vision, that dedication to a perpetual planet, which we are proud to stand by. **For as long as it is needed.**

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